Folsom, Schultz & Bonde 1926

University of Maine

IMPERIAL BUREAU OF MYCOLOGY 8 JAN. 1927

Maine Agricultural Experiment Station

ORONO

BULLETIN 331 MARCH, 1926

POTATO DEGENERATION DISEASES: NATURAL SPREAD AND EFFECT UPON YIELD

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BULLETIN 331

POTATO DEGENERATION DISEASES: NATURAL SPREAD AND EFFECT UPON YIELD.[1]

DONALD FOLSOM, E. S. SCHULTZ,[2] AND REINER BONDE

SUMMARY

(1) Tests of the effects of degeneration diseases upon the yield rate of potatoes were continued in 1924. From two to five plots were planted with each diseased or healthy part of a tested strain. Spindle-tuber in Green Mountains and in Irish Cobblers reduced the yield rate of completely infected stocks to 20 per cent below the yield rate of healthy stocks of the same strains. Mild mosaic in similar comparisons in Green Mountain strains reduced the yield rate to from 8 to 15 per cent below that of healthy stocks. Rugose mosaic reduced the yield rate 50 per cent. Each 10 per cent reduction amounted to from 30 to 40 bushels an acre (or 11 to 15 barrels.) Mild mosaic reduced the yield about the same in the third year of apparent infection as in the second. Disease present to the extent of 50 per cent or less did not reduce the yield in proportion to the reduction by a 100 per cent infection, and did not reduce the yield rate more than uncontrolled differences in soil and other environmental conditions did. Inferior soil reduced the yield of a healthy stock below that of a completely diseased stock on good soil, and increased the injurious effects of mild mosaic.

(2) Tests of the effects on yield rate in 1925 were made in Green Mountains alone, with three plots of each stock in a series. Spindle-tuber reduced the yield rate of a completely infected stock to 25 per cent below the yield rate of a healthy stock. Mild mosaic reduced the yield rate to the same extent as spindle-tuber, while rugose mosaic reduced the yield rate about 60 per cent.

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[1]This bulletin contains results of investigations conducted as a co-operative project by the Department of Plant Pathology of the Maine Agricultural Experiment Station and the Office of Cotton, Truck and Forage Crop Disease Investigations of the Bureau of Plant Industry of the U. S. Department of Agriculture.

[2]Plant Pathologist, U. S. Department of Agriculture.

Each 10 per cent reduction amounted to about 40 bushels or 14 barrels an acre. Giant-hill stock yielded slightly better than healthy. With spindle-tuber or mosaic present in only part of the stock, the yield was reduced more than was proportional to the reduction in the completely diseased lots.

(3) A study of the amount and distance of spread of mosaic and spindle-tuber from diseased to healthy fields was continued and concluded. In 1923, thirty-six fields were sampled. The samples, grown in 1924, showed that in 1923 one or both diseases often had spread, in some places infecting a third of the plants in the first five healthy rows next to diseased rows, and in some other places spreading across the healthy field as far as the fiftieth row.[3] A general increase of disease due to spread from one hill to another in partly diseased stock, was disclosed as being more frequent and as being probably greater in effect than the spread from one field to another. Therefore the secondary effects of field-to-field spread may be worse than the immediate effects.

(4) For some unknown reason these diseases did not increase or spread in some instances where conditions seemed favorable. They also did not spread in most of the fields where there was some isolation from diseased stock. When present, their increase was checked by roguing.

(5) Although spindle-tuber seemed to increase about as rapidly as mild mosaic when no tuber selection was attempted, spindle-tuber was easier to reduce by roguing tuber-unit seed-plots than was mild mosaic. Evidence is presented indicating that other insects in addition to aphids transmit these diseases, and that they probably do not transmit similarly.

(6) Other degeneration diseases such as leafroll and rugose mosaic are easier to eliminate than mild mosaic.

(7) Incompleteness of tuber infection presents a difficulty in attempting to rogue early, as it often is accompanied by a delayed appearance of symptoms.

(8) Tuber weight has importance in tuber-unit seed-plot methods more for other reasons than because of any consistent correlation of disease percentage with weight.

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[3]Rows here are usually a little less than three feet apart, that is, from middle to middle of adjacent rows.

(9) Contact between hills increases the spread of disease but is not necessary for its spread.

(10) Spread was more marked in the southwestern part of the State than in the northeastern part.

(11) Parts of a strain may become different from each other through unequal contamination by disease. At present the probable relative value of seed stocks in storage can be determined more dependably by advance testing in a warmer environment than by forecasting from field observations, or than by ascertaining the origin of the stock or strain two or more years previously.

INTRODUCTION

The first report of this nature[4] was issued recently and contained a brief general discussion of potato degeneration as a commercial problem in Maine. It also gave the results of the tests conducted in 1923 for determining the effect, upon the yield rate, of mild mosaic and spindle-tuber in Green Mountains and of spindle-tuber in Irish Cobblers.[5] It described how samples from commercial fields, dug in 1922 and planted in 1923, showed that mosaic and spindle-tuber spread from one field to another and from one hill to another. Before these samples could be completely studied in 1923 as to spindle-tuber, the selection of a second series was planned based on observations made while inspecting certain commercial fields. This second series of samples was dug in 1923 and planted in 1924. The results are presented in this bulletin. As will be seen, the second test confirmed the results of the first. Tests of the effects of these diseases upon the yield rate were repeated in 1924 and 1925, and the results are described here. It is also thought to be desirable to include the results of

[4]Folsom, Donald, and E. S. Schultz. The importance and natural spread of potato degeneration diseases. Maine Agr. Exp. Sta. Bul. 316. 1924.

[5]The various degeneration diseases of potato will not be described here because they are discussed fully in readily available bulletins such as: Folsom, Donald. Potato mosaic. Maine Agr. Exp. Sta. Bul. 292. pp. 157-184. 1920.——Potato leafroll. Maine Agr. Exp. Sta. Bul. 297. p. 37-52.——Potato spindle-tuber. Maine Agr. Exp. Sta. Bul. 312. p. 21-44. 1923. Schultz, E. S. Why potatoes run out. U. S. Dept. Agri. Farmers' Bul. 1436. 1924.

tests of tuber-unit seed-plots as a means of keeping potato stocks practically healthy.

EFFECT UPON YIELD IN 1924

The three strains used in 1923[6] were used again in 1924. Strain BA, of the Green Mountain variety, was represented by five kinds of stock, namely: "healthy" stock grown in the Aroostook Farm seed-plot in 1923; "spindle-tuber" stock used in the yield test of 1923 where it was unavoidably exposed to mosaic infection; "mild mosaic" stock hill selected as showing this disease in 1923; and "partly healthy" stock grown in 1923 either in the yield test in the healthy two-row plots alternating with the spindle-tuber plots, or in a two-acre field adjoining an Irish Cobbler field with about 30 per cent of the hills spindle-tuber. The percentages of disease present in 1924 in the yield-test plots of these five types, are given in Table 1. There it is shown that the five series of plots differed from each other in regard to disease percentages. At least four-fifths of the mosaic in any one series was of the mild type. A trace of leafroll was observed in one plot. Other diseases were absent or negligible.

The five lots of seed of Green Mountain strain BA, after having been disinfected in cold formaldehyde solution, were cut by one person into seed-pieces approximating and averaging one ounce in weight. The seed was planted on May 24, in rows three feet apart, with a two-man planting machine. About 1650 pounds of 5-8-7 fertilizer per acre was used. The plots were numbered in the order of location and of time of planting. Plots 1 to 20 were of two rows each, consisting of about one-thirtieth of an acre. Plots 21 to 25 were of one row each. A plot of every lot of seed was planted before any one lot was used again, so that every fifth plot was of the same lot of seed. This replication was intended to serve as a check on possible soil differences although an apparently uniform area was used. The usual spraying schedule was followed for the control of certain foliage diseases. The crop was dug about two weeks after the death of the plants resulting from the frost of September 26. The net weight of the yield from each plot was determined on a large platform scales (sensitive to ± 2.5 pounds) by difference between the gross

[6] Folsom, Donald, and E. S. Schultz. *Op. cit.*, p. 3-8.

weight in barrels and the weight of the barrels. Knowing the number of hills, the size of each plot, and the weight of the crop, the yield rate in pounds per hill and in barrels[7] and bushels per acre was calculated and is given in Table 1, together with the averages.

TABLE 1.

Effect of spindle-tuber and mild mosaic upon yield in test plots, 1924, in Green Mountain strain BA.

Plot No.[1]	Type of plot	Disease percentages		Yield rate		
		Mosaic[2]	Spindle-tuber	Per hill	Per acre	
					Barrels	Bushels
		%	%	Pounds		
1	"Healthy"	3	6	2.02	149	408
6		----	5	2.23	151	413
11		3	8	2.19	151	413
16		2	9	2.11	146	401
21		----	6	1.99	137	378
Ave.		3	7	2.11	147	403
2		100	3	2.07	145	398
7	"Mild	----	5	1.86	127	348
12	mosaic"	99	3	2.01	138	379
17		100	5	1.85	129	355
22		----	6	1.91	134	369
Ave.		100	4	1.94	135	370
3	"Spindle-	46	100	1.54	127	348
8	tuber"	----	100	1.70	120	329
13		35	100	1.76	122	336
18		42	100	1.66	117	321
23		----	100	1.63	109	301
Ave.		41	100	1.66	119	327
4	"Partly	24	38	2.11	148	406
9	healthy";	----	27	2.09	144	396
14	from yield	16	38	2.16	150	411
19	test plots	19	39	1.95	133	365
24		----	26	2.13	146	401
Ave.		20	34	2.09	144	396
5	"Partly	12	8	2.12	151	411
10	healthy";	----	9	2.12	151	411
15	from next	11	16	2.05	145	398
20	Cobblers	7	12	2.08	145	398
25		----	11	1.93	136	374
Ave.		10	11	2.06	146	398

[1]The plots were numbered consecutively from north to south. Each plot consisted of two rows 250 feet long, except for plots 21 to 25 inclusive which were each of one row. Each row contained about 200 hills.

[2]At least four-fifths of the mosaic in any one series was of the mild type.

[7]A "barrel" is 2¾ bushels or 165 pounds.

The yield rates given in Table 1 show that in Green Mountain strain BA, mosaic when present in all the hills reduced the yield rate about 8 per cent in pounds per hill and in barrels or bushels per acre, as compared with the "healthy" series. Also, with spindle-tuber present in all the hills and mosaic present in nearly half the hills, the yield rate was reduced about 20 per cent in pounds per hill and in barrels or bushels per acre. Compared with each other, one of the partly healthy series yielded slightly more than the other in pounds per hill and slightly less in barrels or bushels per acre. They yielded about 2 per cent less than the healthy series. Here the presence of mosaic in 20 per cent of the hills and of spindle-tuber in over 30 per cent of the hills, together reduced the yield only one-tenth as much as mosaic in 40 per cent of the hills together with spindle-tuber in 100 per cent. Apparently healthy hills when numerous made up largely for the loss in diseased hills.

Strain BV, Green Mountains, was represented by five kinds of stock, namely: "mild mosaic" stock that was hill selected in 1923 on Aroostook Farm as showing the disease for the first time; "rugose mosaic" stock similarly selected in 1923; "healthy" stock grown in the Aroostook Farm seed-plot in 1923; "partly healthy" stock grown in 1923 on Aroostook Farm in the yield test as healthy hills next to mosaic hills; and "third-year mild mosaic" stock grown in 1923 in the mosaic plots of the yield test. The percentages of disease present in 1924 in the yield-test plots of these five types, are given in Table 2. There it is shown that the five series of plots differed from each other in regard to disease percentages. A trace of leafroll was observed in only one plot. Other diseases were absent or negligible.

The five lots of seed of Green Mountain strain BV were disinfected, cut, and planted in the same way as the seed of strain BA, as described previously. The plots were situated with ends meeting the south plots of strain BA, except for a ten-foot cross aisle. More of the soil was of a somewhat inferior type. The plots were of two rows each except for the two with rugose mosaic, which were of one row each. The arrangement is indicated by the plot numbers in Table 2; each series was distributed regularly over the field except for the rugose mosaic lots. The date of digging and the method of yield determinations were as for the plots of strain BA.

TABLE 2.

Effect of mild mosaic and rugose mosaic upon yield in test plots, 1924, in Green Mountain strain BV.

Plot No.[1]	Type of plot	Disease percentages			Yield Rate		
		Mild mosaic	Rugose mosaic	Spindle-tuber	Per hill	Per acre	
						Barrels	Bushels
		%[2]	%[2]	%[2]	Pounds		
1	"Mild	98	1	24	1.64	114	312
9	mosaic"	100	3	24	1.63	112	307
15		----	----	25	1.65	114	312
Ave.		99	2	24	1.64	113	310
2	"Rugose	[3]	100	1	0.90	61	169
6	mosaic"	[3]	100	3	0.93	64	178
Ave.		----	100	2	0.92	63	174
3	"Healthy"	9	1	5	1.94	129	353
7		9	1	7	1.96	131	360
10		13	0	14	2.00	129	353
13		----	----	8	1.91	129	353
16		----	----	7	1.86	125	343
Ave.		10	1	8	1.93	129	352
4	"Partly	20	3	19	1.70	108	297
8	healthy"	22	2	24	1.74	116	319
11		29	2	35	1.62	111	304
14		----	----	35	1.72	118	324
17		----	----	27	1.65	113	309
Ave.		24	2	28	1.69	113	311
5	"Third-year	99	1	41	1.58	109	300
12	mild mosaic"	100	3	39	1.65	112	307
Ave.		99	2	40	1.62	111	304

[1]The plots were numbered consecutively from north to south. Each consisted of two rows 250 feet long, except for plots 2 and 6, which were each of one row. Each row contained about 190 hills.

[2]Percentage based on only one row.

[3]Mild mosaic if present would probably be masked by the rugose mosaic.

The yield rates, given in Table 2, show that in Green Mountain strain BV, when mild mosaic was present in all the hills with spindle-tuber also in 25 per cent, the yield rate was reduced about 15 per cent in pounds per hill and about 12 per cent in barrels or bushels per acre, as compared with the "healthy" series. With rugose mosaic present in all the hills, the yield rate was reduced over 50 per cent both per hill and per acre. Evidently the two types of mosaic are different in their effects on the yield as well as in their foliage characteristics. The third-year mild mosaic plots had more spindle-tuber and yielded somewhat less

than the other mild mosaic plots. Apparently mild mosaic does not become more severe from year to year. The partly healthy series with 50 per cent of the hills diseased, as compared with the "healthy" series with about 20 per cent of the hills diseased, yielded about 12 per cent less both per hill and per acre. This result is not the same as that with partly healthy stock in Green Mountain series BA, where such stock was about the same in yielding power as the "healthy" possibly because of better soil favoring compensation by the healthy hills for the loss in the diseased hills.

TABLE 3.

Comparison of yield rates of Tables 1 and 2, giving difference between means and probable error of difference[1]; also ratio between difference and its probable error.

Comparison	Means compared		Difference between means and P.E. of difference	Ratio between difference and P.E.
1.	Table 1, "healthy", pounds per hill, 2.108±.02	Table 1, "mild mosaic," pounds per hill, 1.940±.026	.168±.038	4.4:1
2.	Ditto	Table 1, "spindle-tuber," pounds per hill, 1.658±.022	.450±.036	12.5:1
3.	Ditto	Table 1, "partly healthy"; from yield test plots, pounds per hill, 2.088±.022	.020±.036	1:1.8
4.	Ditto	Table 1, "partly healthy"; from next Cobblers, pounds per hill, 2.060±.021	.048±.035	1.4:1
5.	Table 1, "healthy", bushels per acre, 402.6±4.0	Table 1, "mild mosaic," bushels per acre, 369.8±5.3	32.8±6.6	5.0:1
6.	Ditto	Table 1, "spindle-tuber," bushels per acre, 327.0±4.7	75.6±6.2	12.2:1
7.	Ditto	Table 1, "partly healthy"; from yield test plots, bushels per acre, 395.8±4.9	6.8±6.3	1.1:1
8.	Ditto	Table 1, "partly healthy"; from next Cobblers, bushels per acre, 398.4±4.1	4.2±5.7	1:1.4
9.	Table 2, "mild mosaic," pounds per hill, 1.640±.003	Table 2, "third-year mild mosaic," pounds per hill, 1.605±.012	.035±.012	2.9:1
10.	Table 2, all mild mosaic, pounds per hill, 1.630±.008	Table 2, "rugose mosaic," pounds per hill, 0.915±.007	.715±.011	65.0:1

Comparison of yield rates of Tables 1 and 2, giving difference between means and probable error of difference[1]; also ratio between difference and its probable error.—Concluded.

Comparison	Means compared		Difference between means and P.E. of difference	Ratio between difference and P.E.
11.	Table 2, "healthy", pounds per hill, 1.934±.014	Table 2, all mild mosaic, pounds per hill, 1.630±.008	.304±.016	19.0:1
12.	Ditto	Table 2, "rugose mosaic," pounds per hill, 0.915±.007	1.019±.016	63.7:1
13.	Ditto	Table 2, "partly healthy," pounds per hill, 1.686±.014	.248±.020	12.4:1
14.	Table 1, "healthy", pounds per hill, 2.108±.028	Table 2, "healthy," pounds per hill, 1.934±.014	.174±.031	5.6:1
15.	Table 1, "mild mosaic," pounds per hill, 1.940±.026	Table 2, all mild mosaic, pounds per hill, 1.630±.008	.310±.027	11.5:1
16.	Table 2, "mild mosaic," bushels per acre, 310.3±0.9	Table 2, "third-year mild mosaic," bushels per acre, 303.5±1.7	6.8±1.9	3.6:1
17.	Table 2, all mild mosaic, bushels per acre, 307.6±1.3	Table 2, "rugose mosaic," bushels per acre, 173.5±2.1	134.1±2.5	53.6:1
18.	Table 2, "healthy", bushels per acre, 352.4±1.6	Table 2, all mild mosaic, bushels per acre, 307.6±1.3	44.8±2.1	21.3:1
19.	Ditto	Table 2, "rugose mosaic," bushels per acre, 173.5±2.1	178.9±2.6	68.8:1
20.	Ditto	Table 2, "partly healthy," bushels per acre, 310.6±3.0	41.8±3.4	12.3:1
21.	Table 1, "healthy", bushels per acre, 402.6±4.0	Table 2, "healthy," bushels per acre, 352.4±1.6	50.2±4.3	11.7:1
22.	Table 1, "mild mosaic," bushels per acre, 369.8±5.3	Table 2, all mild mosaic, bushels per acre, 307.6±1.3	62.2±5.5	11.3:1
23.	Table 1, "healthy," bushels per acre, 402.6±4.0	Same stock and strain (BA) as of Table 1, "healthy," but in different field, bushels per acre, 392.3±2.6	10.3±4.8	2.1:1
24.	Table 2, "healthy", bushels per acre, 352.4±1.6	Same stock and strain (BV) as of Table 2, "healthy," but in different field, bushels per acre, 400.0±3.1	47.6±3.5	13.6:1
25.	Stock of strain BA in same field with strain BV bushels per acre, 392.3±2.6	Stock of strain BV in same field with strain BA, bushels per acre, 400.0±3.1	7.7±4.0	1.9:1

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

Further comparisons are made in Table 3, by means of mathematical formulae, which show that certain differences pointed out in the preceding paragraph are significant. Comparisons 1, 2, 5,

and 6 in Table 3 show that in strain BA the yield rate per hill and per acre was reduced significantly by mild mosaic and spindle-tuber when either disease was present in all the hills. In the same strain it was not reduced significantly when up to 50 per cent of the hills were diseased (comparisons 3, 4, 7, and 8). That is, any effect of the disease present was compensated by expansion of the healthy hills and was hidden by the effect of soil variation or of other uncontrolled factors.

As is shown in Table 3 in comparisons 9, 10, 16, and 17, in strain BV the difference between the "third-year mild mosaic" plots and other mild mosaic plots in yield rate is much less significant than the difference between all the mild mosaic plots together and the rugose mosaic plots (ratio of about 3 to 1 as against ratio of 50 and more to 1.) The "third-year mild mosaic" plots had more spindle-tuber than the other mild mosaic plots, which may explain some of the slight difference observed. It seems obvious that much greater difference in yield results from a difference in the kind of mosaic than results from letting the mild kind run for a longer term of years. It may be added here that the writers have some ten-year-old lots of mild mosaic that have been perpetuated in insect cages to prevent contamination by new diseases. Each year part of such stocks are planted in the open field near other stocks that have rugose mosaic of recent infection. Thus compared, the rugose mosaic is much worse than the mild, and the long-time mild mosaic stocks are about the same as in previous years. They fluctuate with the season as does healthy stock, but they are much different from rugose mosaic.

Comparisons 1, 3, 5, 7, 11, 13, 18, and 20, show that in strain BV there was a much more significant reduction of the yield rate by 100 per cent mild mosaic and by 50 per cent disease (mild mosaic and spindle-tuber) than in strain BA. This can be explained best after a comparison of the healthy strains and of the soil of the plots. The area planted with strain BV contained more of the inferior type of soil (Washburn, dark, low-land, or spruce-growth type) than the area planted with strain BA. This reduced the yield of both healthy and mosaic stocks in the BV strain as is shown by comparisons 14, 15, 21, and 22. Further effects of the inferior type of soil seem to have been that with mosaic reducing the yield more, the healthy hills in partly diseased lots did not make up yield for the diseased hills. The

suggestion may arise that there was a difference in inherent vigor between the two healthy strains. This suggestion is met by the fact that in another series of plots, on an area not referred to before, the BV strain yielded better than the BA strain, though the difference was not significant (see last comparison in Table 3.) Also, strain BV yielded lower on the dark soil than elsewhere; the time of planting was also different, however. (See the next to the last comparison in Table 3.) It therefore seems fair to conclude that the two strains were inherently similar, and that soil differences caused the BV disease-test plots to yield less, even to such an extent that the healthy plots yielded less than the mild mosaic plots in the BA strain series.

TABLE 4.

Effect of spindle-tuber upon yield in test plots, 1924, in an Irish Cobbler strain.

Plot No.[1]	Type of plot	Percentage of spindle-tuber[2]	Yield rate		
			Per hill[3]	Per acre	
				Barrels	Bushels
		%	Pounds		
1	"Spindle-tuber"	98	1.25	80	218
4		97	1.23	82	224
7		97	1.24	77	211
Ave.		97	1.24	80	218
2	"Partly healthy I"	11	1.62	112	308
5		26	1.54	103	282
8		32	1.52	100	275
Ave.		23	1.56	105	288
3	"Partly healthy II"	11	1.58	108	296
6		18	1.56	105	287
9		20	1.41	93	255
Ave.		16	1.52	102	279

[1]The plots were numbered consecutively from north to south. Each consisted of two rows 250 feet long.

[2]A trace of rugose mosaic was noted. Mosaic of the milder types is hard to recognize when in Irish Cobblers, so that no determination was attempted.

[3]The spindle-tuber rows averaged about 180 hills and the others about 190.

The Irish Cobbler strain was represented by "spindle-tuber" stock grown from tubers selected in the bin as diseased, by "partly healthy I" stock grown from tubers selected as healthy looking in the bin from a lot grown next to a diseased row in 1923, and by

"partly healthy II" stock grown in the Aroostook Farm seed plot in 1923. The first two lots were grown on Aroostook Farm in 1923, in the same field. The percentages of disease present in 1924 in the yield-test plots of these three types, are given in Table 4, except for a trace of rugose mosaic and of leafroll. The spindle-tuber percentage was markedly different in the "spindle-tuber" series as compared with the others, though it will be noted that during tuber selection some healthy material was unavoidably included because of the intergrading in shape of healthy and diseased tubers.

TABLE 5.

Comparison of yield rates of Table 4, giving difference between means and probable error of difference[1]; also ratio between difference and its probable error.

Means compared		Difference between means and P.E. of difference	Ratio between difference and P.E.
"Partly healthy II," pounds per hill, 1.517±.030	"Spindle-tuber," pounds per hill, 1.240±.003	.277±.030	9.2:1
Ditto	"Partly healthy I," pounds per hill, 1.560±.017	.043±.034	1.3:1
"Partly healthy II," bushels per acre, 279.3±6.9	"Spindle-tuber," bushels per acre, 217.7±2.1	61.6±7.2	8.6:1
Ditto	"Partly healthy I," bushels per acre, 288.3±5.5	9.0±8.8	1.0:1

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

The three lots of Irish Cobbler seed were handled as the Green Mountains had been, the plots being alongside those of the Green Mountain BV strain with the ends meeting the north plots of the BA strain. The arrangement of plots is indicated by the plot numbers in Table 4; a plot of each type of seed was planted before any one type was used again, so that the distribution in the field was similar and regular. The crop was dug on September 26 and was weighed as for the Green Mountain plots.

The yield rates, given in Table 4, show that in this Irish Cobbler strain, when spindle-tuber was present in practically all the hills, the yield rate was reduced over 20 per cent as compared with stock with about one-fifth of the hills diseased. The "partly healthy I" series was somewhat more diseased than the "partly healthy II" and yielded a little more. Further comparisons made in Table 5 by means of the proper formulae, show that the difference between the two partly healthy lots of seed was not significant while the difference between each "partly healthy" lot and the diseased was significant.

It may be pointed out here that the percentage of stand was reduced by spindle-tuber (see foot-note of Table 4.) This is correlated with greater bruising injury of spindle-tuber cut seed, which was apparent during the planting operation. This is one reason for believing that the methods used were more representative of growers' practices than hand-planting would be. At present it seems better to use such representative practical methods than to use technique that is more refined but less significant to the average grower.

EFFECT UPON YIELD IN 1925

Tests in 1925 were restricted to Green Mountains. Lots were compared that were respectively healthy, mild mosaic, rugose mosaic, spindle-tuber, giant-hill, and partly diseased because of exposure to new infection in 1924. All the seed came from plots grown on Aroostook Farm in 1924. The seed was cut uniform in size, averaging 1.5 ounces in weight. Planting was done with a machine of the two-man type, on May 21, applying 5-8-7 fertilizer at the rate of about 1500 pounds per acre.

The test comprised 27 plots, each consisting of two rows 200 feet long. There were 9 plots in a section. The first section contained triplicated plots of healthy stock from the seed-plot, of healthy stock from next to mild mosaic stock, and of healthy stock from next to spindle-tuber stock. All were of the same commercial strain (A), grown on Aroostook Farm since 1922 inclusive. As is shown in Table 6, about 15 per cent of the hills were diseased from exposure to infection in 1924, as against 3 per cent diseased in the seed-plot stock. This slight difference in disease

TABLE 6.

Effect of certain degeneration diseases upon yield in test plots, 1925, in Green Mountains.

Plot No.[1]	Strain	Type of plot	Disease percentages				Yield rates					
							Total			Primes[3]		
			Mild mosaic	Rugose mosaic	Spindle-tuber	Giant-hill	Per hill	Per acre		Per hill	Per acre	
								Barrels	Bushels		Barrels	Bushels
			%	%	%	%	Lbs.			Lbs.		
1	A	Next mild mosaic 1924	16	0	T[2]	0	1.77	137.5	378.1	1.56	121.2	333.4
4			11	1	0	0	1.77	133.1	366.0	1.59	119.5	328.5
7			15	1	1	0	1.67	133.1	366.0	1.50	119.5	328.5
Ave.			14	1	T	0	1.74	134.6	370.0	1.55	120.1	330.1
2	A	Healthy	0	0	0	0	1.80	144.1	396.3	1.59	127.6	350.9
5			4	0	0	0	1.75	144.1	396.3	1.55	127.2	349.7
8			4	0	0	0	1.81	143.0	393.3	1.63	128.5	353.3
Ave.			3	0	0	0	1.79	143.7	395.3	1.59	127.8	351.3
3	A	Next spindle-tuber 1924	5	3	10	0	1.69	133.1	366.0	1.49	116.8	321.3
6			8	2	8	0	1.56	132.0	363.0	1.39	118.3	325.5
9			7	1	6	0	1.63	135.3	372.1	1.46	120.8	332.1
Ave.			7	2	8	0	1.63	133.5	367.0	1.45	118.6	326.3
10	BA	Mild mosaic	100	0	1	0	1.28	102.3	281.3	1.14	90.6	249.3
13			100	0	0	0	1.27	100.1	275.3	1.11	87.3	240.2
16			100	T	1	0	1.21	94.6	260.2	1.05	81.4	223.9
Ave.			100	T	1	0	1.25	99.0	272.3	1.10	86.4	237.8
11	BA	Healthy	3	0	0	0	1.64	134.2	369.1	1.46	119.7	329.1
14			3	0	0	0	1.69	133.1	366.0	1.56	122.3	336.4
17			1	T	1	0	1.68	132.0	363.0	1.52	119.2	327.9
Ave.			2	T	T	0	1.67	133.1	366.0	1.51	120.4	331.1

Effect of certain degeneration diseases upon yield in test plots, 1925, in Green Mountains—Concluded.

Plot No.[1]	Strain	Type of plot	Disease percentages				Yield rates					
							Total			Primes[3]		
			Mild mosaic	Rugose mosaic	Spindle-tuber	Giant-hill	Per hill	Per acre		Per hill	Per acre	
								Barrels	Bushels		Barrels	Bushels
			%	%	%	%	Lbs.			Lbs.		
12	BV	Rugose mosaic	----	100	0	0	0.75	56.1	154.3	0.49	35.7	98.0
15			----	100	T	0	0.65	48.4	133.1	0.44	33.0	90.8
18			----	100	0	0	0.66	47.3	130.1	0.42	30.6	84.1
Ave.			----	100	T	0	0.69	50.6	139.2	0.45	33.1	91.0
19	BA	Spindle-tuber	0	0	100	0	1.19	93.5	257.1	0.94	73.9	203.3
22			0	0	100	0	1.25	97.9	269.2	1.03	80.5	221.4
25			0	0	100	0	1.18	92.0	252.9	0.96	75.2	206.9
Ave.			0	0	100	0	1.21	94.5	259.7	0.98	76.5	210.5
20	A	Healthy	3	0	T	0	1.60	125.4	344.9	1.40	110.0	302.5
23			1	0	0	0	1.60	129.8	357.0	1.41	116.6	320.7
26			1	0	0	0	1.62	126.5	347.9	1.44	112.2	308.6
Ave.			2	0	T	0	1.61	127.2	349.9	1.42	112.9	310.6
21	A	Giant-hill	2	1	0	100	1.65	125.4	344.9	1.55	118.1	324.9
24			2	1	T	100	1.60	126.5	347.9	1.48	118.4	325.5
27			4	T	0	100	1.69	131.6	361.8	1.60	124.3	341.8
Ave.			3	1	T	100	1.65	127.8	351.5	1.54	120.3	330.7

[1]The plots were numbered consecutively from east to west. Each plot consisted of two rows 200 feet long. Each row contained from 161 to 198 hills.

[2]"T" (trace) designates less than one-half of 1 per cent.

[3]Those passing over an Irish Cobbler screen of a Boggs grader.

TABLE 7.

Comparison of yield rates of Table 6, giving difference between means and probable error of difference[1]; also ratio between difference and its probable error.

Comparison No.[2]	Plot series compared		Difference between means and its P.E. (with ratio of difference to its P.E.)			
	Yielding more in total per acre	Yielding less in total per acre	Total per acre	Primes per acre	Total per hill	Primes per hill
			Bushels	Bushels	Pounds	Pounds
1	Healthy of series 11, 14, 17	Rugose mosaic	226.8±4.5 (50.4:1)	240.1±3.0 (80.0:1)	0.983±.019 (51.7:1)	1.063±.020 (53.2:)
2	Mild mosaic	Rugose mosaic	133.1±5.0 (26.6:1)	146.8±4.5 (32.6:1)	0.536±.021 (27.0:1)	0.650±.019 (34.2:1)
3	Healthy of series 11, 14, 17	Mild mosaic	93.7±3.7 (25.3:1)	93.3±4.6 (20.3:1)	0.417±.015 (27.8:1)	0.413±.022 (18.8:1)
4	Healthy of series 20, 23, 26	Spindle-tuber	90.2±4.1 (22.0:1)	100.1±4.5 (22.2:1)	0.400±.013 (30.8:1)	0.440±.016 (27.5:1)
5	Giant-hill	Spindle-tuber	91.8±4.6 (20.0:1)	120.2±5.0 (24.0:1)	0.440±.019 (23.1:1)	0.566±.024 (23.6:1)
6	Healthy of series 2, 5, 8	Healthy of series 20, 23, 26	45.4±2.7 (16.8:1)	40.7±3.0 (13.6:1)	0.180±.011 (16.4:1)	0.173±.014 (12.4:1)
7	Ditto	Healthy of series 11, 14, 17	29.3±2.2 (13.3:1)	20.2±2.4 (8.4:1)	0.117±.013 (9.0:1)	0.077±.021 (3.7:1)
8	Ditto	Next spindle-tuber 1924	28.3±2.5 (11.3:1)	25.0±1.8 (13.9:1)	0.160±.023 (7.0:1)	0.143±.021 (6.8:1)
9	Ditto	Next mild mosaic 1924	25.3±2.9 (8.7:1)	21.2±2.1 (10.1:1)	0.050±.021 (2.4:1)	0.040±.020 (2.0:1)
10	Healthy of series 11, 14, 17	Healthy of series 20, 23, 26	16.1±3.4 (4.7:1)	20.5±3.7 (5.5:1)	0.033±.010 (6.3:1)	0.096±.017 (5.6:1)
11	Giant-hill	Ditto	1.6±4.3 (1:2.7)	20.1±4.6 (4.4:1)	0.040±.016 (2.5:1)	0.126±.020 (6.3:1)

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.
[2]Comparison made in order of decreasing ratio of difference to its P.E., as to total bushels per acre.

was accompanied by a decrease in yield somewhat out of proportion, compared with the decrease in yield shown in 100 percent diseased plots in the second and third sections of the test. Also, the decrease in yield is shown in Table 7 to be less significant than the difference in yield between the healthy strain A stock planted in the first section and the same stock planted in the third section.

The second section of the test contained triplicated plots of healthy stock from the seed-plot (strain BA), of mild mosaic stock (strain BA), and of rugose mosaic stock (strain BV). Here mild mosaic, in 100 per cent of the hills, reduced the yield per acre about 94 bushels (about 34 barrels) or about 25 per cent. Rugose mosaic, in 100 per cent of the hills, reduced the yield per acre about 227 bushels (about 83 barrels) or about 60 per cent. As is shown in Table 7, the most significant effects on yield in the whole test are those of rugose mosaic, when compared with either mild mosaic or healthy stock.

The third section of the test contained triplicated plots of healthy stock from the seed-plot (strain A), of giant-hill stock (strain A), and of spindle-tuber stock (strain BA). The first two sections were dug on September 22 at about the time the tops had been killed by frosts, but the third section was not dug until September 30. This delay was made because the giant-hill plants were resistant to frost injury and their full yield was desired. The spindle-tuber lots were somewhat resistant to frost likewise. When dug the giant-hill crop was skinned rather badly because of the immaturity of the tubers, and the spindle-tuber crop was badly bruised as usual. The giant-hill disease, in 100 per cent of the hills, slightly increased the yield rate, probably due to the frost resistance and longer life of the tops, while the spindle-tuber disease, in 100 per cent of the hills, reduced the yield per acre about 90 bushels (about 33 barrels) or about 25 per cent, which is like the effect of mild mosaic in this same test.

The number of hills varied from row to row, so that the yield rate was also determined in pounds per hill. Further, the primes were sorted out by means of a mechanical grader and the yield of primes per acre and per hill was determined. In general the effect on yield was about the same, whether calculated for total or primes, per acre or per hill. This is brought out in Table 7. Rugose mosaic had the most depressing effect, followed by mild mosaic and spindle-tuber, then followed by the effect of location

on healthy strains together with the effect of a small amount of disease, and giant-hill had a slightly elevating effect. Rugose mosaic and spindle-tuber reduced the yield of primes more than they reduced the total yield.

It should be added that some plots had about 1 per cent of the hills affected with yellow-top, which is not mentioned in Table 6.

SPREAD OF DEGENERATION DISEASES BETWEEN ROWS AND FIELDS IN 1923

In 1923, 36 fields were sampled that were either practically or comparatively healthy. That is, in most of them there was not more than about 5 per cent disease. In general the procedure of the preceding year was followed.[8] Samples were taken at increasing distances from near-by diseased fields. Each sample consisted of from 25 to 50 tubers taken from consecutive hills, one tuber from each hill. The sacked and labeled samples were stored and planted the next season, when the effects of the spread of disease in the first generation became apparent in the second generation or progeny.

The facts regarding these fields and samples are summarized in Table 8. Table 9 gives the facts concerning the corresponding diseased fields and samples. The healthy fields are listed in Table 8 in an arbitrary manner—according to the alphabetical arrangement of the growers' names in the original records.

It will be difficult for the reader to find time to draw conclusions from these tables. The writers therefore have attempted to bring out the principal lessons as briefly as possible. In doing so, they have found in general that the problem is complex, that the spread of disease while obvious in some cases is not as great as might be expected, and that the spread of disease varies greatly without the causes of such variation being apparent.

These general deductions may suffice the general reader. For the readers with greater interest, the various phases of the problem will be considered separately in the next several pages. If this consideration does nothing else, it will probably support the general deductions that have just been presented.

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[8] *Ibid.*, p. 9.

TABLE 8.

Description of healthy fields sampled in 1923[1].

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
		%				%[4]	%[4]	
1	Green Mountain	5 mosaic, 5 spindle-tuber	5	Row W–1	6	10	11	Total rows 61.
				Row W–6	50	30	20	
				Row W–11	48	40	12	
				Row W–42	50	32	12	
				Row W–61	50	6	14	
2	Ditto	5 to 10 mosaic 3 spindle-tuber	7 to 29	Row N–1	50	38	16	
				Row N–13	53	25	10	
				Row N–33	49	26	6	
				Row S–60	50	50	8	
				Row S–30	50	64	8	
				Row S–10	42	60	19	
				Row S–1	50	32	0	
3	Ditto	2 mosaic, rogued August 23, no spindle-tuber	150	N.W. corner	48	27	0	
			150	Row N–145, W. end	49	14	0	
			270	Row N–145, E. end	50	28	0	
			1,90	Row N–290, E. end	50	4	0	
4	Irish Cobbler	6 mosaic, no spindle-tuber	7	Row W–1	49	10[8]	0	
				Row W–20	49	10[8]	0	
				Row W–40	50	22[8]	0	
				Row W–60	51	10[8]	0	
5	Green Mountain	No mosaic left August 25, no spindle-tuber	7	Row N–1	50	48	6	Total rows 72.
				Row N–5	50	20	8	
				Row N–10	49	14	0	
				Row N–20	50	2	0	
				Row N–40	49	4	0	
				Row S–20	49	8	0	

Description of healthy fields sampled in 1923—Continued.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
		%				%[4]	%[4]	
				Row S–10	50	6	0	
				Row S–5	49	14	6	
				Row S–1	49	16	0	
6[13]	Irish Cobbler	Trace[12] spindle-tuber	8	Row E–1	48	2	0	Mosaic of rugose type in progeny of sample E–1.
				Row E–10	50	0	0	
				Row E–50	50	2[8]	0	
				Row E–70	49	8[8]	0	
7[13]	Ditto	Trace leaf-roll, no spindle-tuber	7	Row W–1	50	2[8]	8	Total rows 66.
				Row W–5	50	0	10	
				Row W–10	50	2[8]	2	
				Row W–50	50	2[8]	4	
				Row E–5	26	0	0	
				Row E–1	25	0	4	
8[13]	Ditto	1 spindle-tuber	40	Row S–1	49	0	4	
				Row S–10	52	0	4	
				Row S–40	49	0	0	
				Row S–80	47	4[8]	2	
				Row S–120	51	6[8]	2	
9	Green Mountain	2-4 mosaic, no spindle-tuber	50	South	49	29	8	North sample 2 per cent leafroll in progeny.
				S. middle	50	26	2	
				Middle	45	11	0	
				N. middle	49	29	2	
				North	52	25	0	
10	Irish-Cobbler	2 spindle-tuber	7	12 feet	50	4[8]	2	Originally of same strain as for fields 6, 7, and 8.
				180 feet	49	12[8]	4	
				480 feet	49	29[8]	8	

Description of healthy fields sampled in 1923—Continued.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
		%				%[4]	%[4]	
11	Green Mountain	Trace mosaic, no spindle-tuber	200	Row E–1	50	42	0	Total rows 56.
				Row E–5	50	28	0	
				Row E–10	50	12	2	
				Row E–20	50	16	8	
				Row E–40	48	17	6	
				Row E–55	49	22	4	
12	Irish Cobbler	1 spindle-tuber	230	Row S–3	50	2[8]	6	
				Row S–13	50	0	6	
				Row S–28	50	0	0	
				Center	50	0	0	
				N.E. corner	49	0	6	
13	Green Mountain	Trace mosaic, rogued no spindle-tuber	4	West	50	2	0	Planted by tuber-units.
				Center	50	4	0	West sample 2 per cent
				East	51	6	0	leafroll in progeny.
14	Spaulding Rose	1 to 2 spindle-tuber	6	Row W–1, N.	47	0	8	Adjoins field 15 on E.
				Row W–1, center	44	0	9	
				Row W–7, center	[illegible]	0	2	
				Row W–7, S.	43	0	2	
				Row W–13, center	48	0	0	
15	Green Mountain	Mosaic rogued, no spindle-tuber	0	Row E–9, N.	51	24	0	Adjoins field 14 on W.
				Row E–9, center	49	8	0	Center sample 2 per cent
				Row E–9, S.	49	4	0	leafroll in progeny.
16	Irish Cobbler	Over 20 spindle-tuber, rogued	6	N.W.	51	0	8	Planted by tuber-units.
				Center	51	0	4	
				S.E.	50	0	6	
17[13]	Irish Cobbler	15 to 20 spindle-tuber	120	Row N–1	48	4	23	Mosaic of rugose type in
				Row N–10	50	2	8	progeny of samples N–1

Description of healthy fields sampled in 1923—Continued.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
		%				%[4]	%[4]	
				Row N 20	50	0	10	and N–10
				Row N 40	47	0	15	
				Row N- 60	46	0	26	
				Row N–85	50	8[8]	26	
18[13]	Irish Cobbler	Trace spindle-tuber	9	Row N–1	50	2[8]	0	
				Row N- 5	49	0	0	
				Row N 10	50	6[8]	0	
				Row N 20	50	12[8]	0	
				Row N–50	50	4[8]	0	
				Row N–100	50	8[8]	0	
19[14]	Green Mountain	Trace mosaic[10], trace spindle tuber	45	East	51	8	4	700 feet E. to W. East sample 2 per cent leaf roll in progeny.
				Center	50	12	2	
				West	49	16	0	
20[14]	Green Mountain	Trace mosaic[10], trace spindle-tuber	7	South	50	0	2	500 feet S. to N.
				Center	51	4	0	
				North	45	4	0	
21[14]	Green Mountain	Trace mosaic[10], trace spindle tuber	7	Row N–1	31	10	0	Total rows 292. N–1 sample 3 per cent leafroll in progeny.
				Row N–10	97	4	11	
				Row N–20	90	13	0	
				Row N–50	99	24	0	
				Row N–100	50	7	7	
				Row N–150	29	7	0	
				Row N- 200	31	6	3	
				Row N–250	30	0	10	
				Row N- 290	30	3	0	
22[14]	Green Mountain	Trace mosaic[10], trace spindle tuber	100	Row N–1	29	7	0	Total rows 146. N–1 sample 3 per cent leafroll in progeny
				Row N–10	30	10	0	
				Row N–20	30	0	0	

Description of healthy fields sampled in 1923—Continued.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
						%[4]	%[4]	
				Row N 50	60	7	0	
				Row S 50	58	7	0	
				Row S 20	60	7	0	
				Row S–10	30	3	0	
				Row S–1	29	7	3	
23	Spaulding Rose	4 mosaic, 3 spindle-tuber	15	Row S–1	28	0	7	
				Row S 5	29	0	3	
				Row S–10	30	0	0	
				Row S–20	25	4	0	
				Row S 38	29	7	0	
				N.W.	29	3	7	
24	Irish Cobbler	No mosaic, 17 spindle-tuber	50	Row N 1	40	0	30	
				Row N 5	32	0	30	
				Row N–10	60	13	23	
				Row N–20	30	0	17	
				Row N 50	31	0	16	
25	Green Mountain	No mosaic[10], no spindle-tuber	7	Row S–1	50	14	2	S–20 sample 24 per cent leafroll in progeny.
				Row S 5	50	6	0	
				Row S 10	50	8	0	
				Row S 15	50	8	0	
				Row S–20	50	2	0	
				Row S–25	50	4	0	
26	Green Mountain	12 mosaic, no spindle-tuber	120	Row N–1	49	29	0	N–20 sample 2 per cent leafroll in progeny.
				Row N–5	49	36	0	
				Row N 10	48	27	0	
				Row N 20	50	54	2	
				Row N–40	49	50	4	
				Row N 80	50	56	0	
				Row N–120	50	60	0	

Description of healthy fields sampled in 1923—Continued.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
						%	%	
27	Green Mountain	2 mosaic, rogued; no spindle-tuber	250	Row E–1	31	13	3	
				Row E–5	30	7	0	
				Row E–10	31	15	0	
				Row E 20	30	0	0	
				Row E–40	29	0	0	
				Row E 100	30	0	0	
				Row E- 350	30	10	0	
				Row E–712	30	10	0	
28	Green Mountain	1 mosaic, no spindle-tuber	40	West	50	2	0	
				Center	50	0	0	
				East	50	2	0	
29	Green Mountain	1 mosaic, no spindle-tuber	20	West	49	10	0	
				Center	49	4	0	
				East	50	0	0	
30	Irish Cobbler	No spindle-tuber	7	Row N–1	30	10[8]	0	
				Row N–5	27	7[8]	0	
				Row N–12	30	20[8]	7	
				East	29	0[8]	0	
31	Spaulding Rose	Trace mosaic, no spindle-tuber	7	Row S 1	30	0	3	S 160 sample 7 per cent leafroll in progeny.
				Row S–5	30	13[11]	0	
				Row S–10	31	3[11]	0	
				Row S–20	30	3[11]	0	
				Row S–40	29	10[11]	0	
				Row S–80	30	7[11]	0	
				Row S–120	29	17[11]	0	
	Green Mountain	No spindle-tuber	7	Row S–160	30	15	0	

Description of healthy fields sampled in 1923—Concluded.

Field	Variety	Disease observed	Aphids on 5 leaves[2]	Samples[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
						%[4]	%[4]	
32	Green Mountain	1 mosaic, rogued; no spindle-tuber	15	N.E.	50	2	0	
				Center	46	0	0	
				S.W.	47	4	0	
33	Green Mountain	5 mosaic, 1 spindle-tuber	[7]	Near I.C.	50	22	4	
				Near S.R.	50	38	0	
				350 feet	50	24	0	
				700 feet	50	8	0	
34	Spaulding Rose	No mosaic; 13, 3, 3, 7, and 4 spindle-tuber respectively in the five samples	[7]	Row W–1	30	0	33	
				Row W–10	29	0	3	
				Row W–20	30	0	7	
				Row W–40	30	0	13	
				Row W–51	30	0	23	
35	Green Mountain	5 mosaic, 1 spindle-tuber	[7]	50 feet	27	19	0	
				150 feet	30	10	0	
36	Irish Cobbler	Trace spindle-tuber	[8]	S.E. 1	50	10[8]	0	
				S.E. 10	46	41[8]	0	
				S.E. 20	48	31[8]	0	
				S.E. 50	50	23[8]	0	
				250 feet	49	4[8]	0	

[1]For description of the corresponding diseased stocks see Table 9.
[2]Taken at random respectively from some plant at the soil, near the soil, at the middle, near the top, and at the top. Reference is made to the compound leaves and not to leaflets.
[3]Rows were numbered from north to south as N–1, N–2, etc., and from any other side in a corresponding fashion. Thus N–5 would mean the fifth row from the north side and S–1, E–1, or W 1 would mean the first row on the south, east, or west respectively.
[4]Based on number of tuber-units diseased. See text p. 74.
[5]See Table 12 regarding hill selections in this field.
[6]In machine-planted plot of 1800 hills.
[7]Not examined for aphids.
[8]Probably approximate percentage of a type that is of uncertain diagnosis in Irish Cobblers because of varietal modification of symptoms and because of similar effects from environmental conditions.
[9]Present but not counted.
[10]After having been rogued.
[11]Of a type not noted in 1923 even if present.
[12]"Trace" indicates less than one-half of 1 per cent.
[13]Fields 6, 7, 8, 10, 17, 18, 8–A, and 9–B were planted with stocks that were originally of the same strain, coming from one farm. Moreover, the same seed stock was used in 1923 to plant fields 6, 7, and 18, and another seed stock for fields 17, 8–A, and 9–B.
[14]Fields 19, 20, 21, and 22 were planted with the same stock.

TABLE 9.

Description of diseased fields nearest to the healthy fields sampled in 1923.[1]

Field[2]	Variety	Position in relation to healthy stock	Disease observed	Aphids on 5 leaves[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
			%			%[4]	%[4]	
1 A[12]	Irish Cobbler	Adjoining on W.	30 spindle-tuber	7				
2–A	Green Mountain	Adjoining on N.	Over 50 mosaic, over 50 spindle-tuber[5]	32				
2–B	Green Mountain	Adjoining on S.	100 mosaic, some spindle-tuber[5]	36				
3 A	Green Mountain	280 feet N.W.	50 mosaic[9]	25	47	83	38	
3 B	Green Mountain	30 feet E. across grass	6 to 12 mosaic, no spindle-tuber	40	47	66	2	
4 A[12]	Irish Cobbler	40 feet W. across road	25 spindle-tuber	200	51	14[9]	57	
5–A	Green Mountain	Adjoining on N.	96 mosaic, 40 spindle-tuber	30	50	100	70	
5–B	Spaulding Rose	Adjoining on S.	4 mosaic, 2 leafroll, 10 spindle-tuber	150	50	2	36	Progeny 2 per cent leafroll
6 A	Green Mountain	Adjoining on E.	90 mosaic, no spindle-tuber	30	47	100	2	
7–A	Green Mountain	Adjoining on W.	94 mosaic, 20 spindle-tuber	25	50	94	36	
7 B	Irish Cobbler	Adjoining on E.	52 spindle-tuber	7	24	0	58	
8–A[11]	Irish Cobbler	Adjoining on S.	16 spindle-tuber	40	49	0	18	

Description of diseased fields nearest to the healthy fields sampled in 1923– Continued.

Field[2]	Variety	Position in relation to healthy stock	Disease observed	Aphids on 5 leaves[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
						%	%	
9–A	Green Mountain	20 feet S. across shrubbery	11 mosaic, 2 spindle-tuber	75	40	46	14	Progeny 4 per cent leafroll
9–B[11]	Irish Cobbler	20 feet N. across grass	32 spindle-tuber	7	24	8[6]	38	
10–A	Spaulding Rose	S.W. across lane	40 mosaic, 18 spindle-tuber	130	28	32	32	
11–A	Green Mountain	Adjoining on E.	65 mosaic, 2 spindle-tuber	100	47	96	8	
11–B	Irish Cobbler	80? feet W. across road	12 mosaic[6], 60 spindle-tuber	150	46	9[6]	78	
12–A	Irish Cobbler	Adjoining on S.	22 spindle-tuber	100	50	0	44	
13–A	Irish Cobbler	Adjoining on W.	21 spindle-tuber, rogued	50	51	0	0	Planted by tuber-units
14–A	Irish Cobbler	115 feet N.	14 spindle-tuber	8	48	0	29	
14–B	Irish Cobbler	80 feet S.W. across railroad	42 spindle-tuber	8	55	0	38	
15–A	Irish Cobbler	15 feet N.	14 spindle-tuber	3	48	0	29	Identical with 14–A
15–B	Irish Cobbler	80 feet S.W. across railroad	42 spindle-tuber	8	57	0	38	Identical with 14–B
16–A	Irish Cobbler	150 feet S.E. across brook	18 spindle-tuber	30, 80	44	0	32	
17–A	Green Mountain	35 feet N.	Much mosaic, and spindle-tuber[5]	?[8]				
17–B	White Bliss Triumph	170 feet S.W.	Much mosaic	250				

Description of diseased fields nearest to the healthy fields sampled in 1923—Continued.

Field[2]	Variety	Position in relation to healthy stock	Disease observed	Aphids on 5 leaves[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
			%			%[4]	%[4]	
18–A	Green Mountain	Adjoining on N.	10 mosaic, no spindle-tuber	8	50	32	0	
19–A	Spaulding Rose	400 feet E.	6 mosaic, 20 spindle-tuber	20	50	4	22	
20–A	Spaulding Rose	S. across lane	10 spindle-tuber	180	29	7	7	
21–A	Spaulding Rose	Adjoining on N.	10 spindle-tuber	180	29	7	7	Identical with 20–A
21–B	Irish Cobbler	225 feet S.	60 spindle-tuber	50	31	10[6]	80	Progeny 3 per cent leafroll
22–A	Irish Cobbler	Adjoining on N.	60 spindle-tuber	50	31	10[6]	80	Identical with 21–B
22–B	Spaulding Rose	Adjoining on S.	Mosaic present, 9 spindle-tuber	20	30	20	38	
23–A	Green Mountain	Adjoining on S.	80 mosaic, 7 spindle-tuber	20	30	97	7	
24–A	Green Mountain	Adjoining on N.	80 mosaic, 7 spindle-tuber	20	30	97	7	Identical with 23–A
25–A	Spaulding Rose	Adjoining on S.	20 spindle-tuber	10	48	2	22	
26–A	Irish Cobbler	Adjoining on N.	25 spindle-tuber	67	49	2[6]	43	
27–A	Irish Cobbler	Adjoining on E.	50 spindle-tuber	85	27	0	56	
28–A	Green Mountain	250 feet W.	96 mosaic, 40 spindle-tuber	30	50	100	70	Identical with 5–A
29–A	Green Mountain	1250 feet W.	96 mosaic, 40 spindle-tuber	30	50	100	70	Identical with 5–A and 28–A

Description of diseased fields nearest to the healthy fields sampled in 1923 Concluded.

Field[2]	Variety	Position in relation to healthy stock	Disease observed	Aphids on 5 leaves[3]	Progeny, 1924			Remarks
					No. of tuber units	Mosaic	Spindle-tuber	
			%			%[4]	%[4]	
30–A	Spaulding Rose	Adjoining on N. Also 270 feet W. of part	4 mosaic, 2 leafroll, 10 spindle-tuber	150	50	2	36	Identical with 5–B. Progeny 2 per cent leafroll.
31–A	Irish Cobbler	Adjoining on S.	7 spindle-tuber	170	30	23[6]	47	
32–A	Green Mountain	270 feet N.E.	30 mosaic[9]	12	50	68	0	
32–B	Green Mountain	330 feet S.W.	96 mosaic, 4 spindle-tuber	5	47	100	11	
32–C	Spaulding Rose	330 feet S.W.	2 mosaic, 10 spindle-tuber	20	30	3	63	
33 A	Irish Cobbler	10 feet E. of part	Mosaic and spindle-tuber present	5	49	18[6]	57	
33 B	Spaulding Rose	10 feet E. of part	14 mosaic, 30 spindle-tuber	7	29	10	28	2 per cent leafroll
34–A	Spaulding Rose	Adjoining on W.	35 spindle-tuber	30	29	24	38	
35–A	Green Mountain	50 feet S. across road	50 mosaic, 2 spindle-tuber	160	30	93	3	
36–A	Irish Cobbler	Adjoining on S.E.	14 spindle-tuber	2, 3, 140	43	86[6]	22	

[1]For description of the healthy fields see Table 8.
[2]The Arabic number is the same as that of the healthy field involved.
[3]Taken at random respectively from some plant at the soil, near the soil, at the middle, near the top, and at the top. Reference is made to the compound leaves and not to leaflets.
[4]Based on number of tuber-units diseased.
[5]Experimental plots.
[6]Probably approximate percentage of a type that is of uncertain diagnosis in Irish Cobblers because of varietal modification of symptoms and because of similar effects from environmental conditions.
[7]Not examined for aphids.
[8]Present but not counted.
[9]Spindle-tuber percentage not recorded.
[10]Several hundred.
[11]Fields 6, 7, 8, 10, 17, 18, 8–A, and 9–B were planted with stocks that were originally of the same strain, coming from one farm. Moreover, the same seed stock was used in 1923 to plant fields 6, 7, and 18, and another seed stock for fields 17, 8–A, and 9 B.
[12]Fields 1–A and 4–A were planted with the same stock.

Date of digging samples. The samples of Irish Cobblers were dug from August 18 to October 1. Those of Green Mountains were dug from September 11 to October 9, and those of Spaulding Rose from September 10 to 24. The healthy samples in any one series were all dug on the same day. Most of the Irish Cobblers died before a killing frost occurred, and several partly killing frosts occurred in some fields of the later varieties before the vines were dead. Most of the samples were dug necessarily before the vines were completely dead.

Most spread to nearest single row. In Fields 9 (south side), 19, 20, 22 (south side), 25, 27, and 33, the sample of healthy Green Mountains nearest to spindle-tuber stock contracted from 2 to 8 per cent spindle-tuber while the more distant samples contracted less, usually none. In Field 7 (east side) the first row of healthy Irish Cobblers nearest to spindle-tuber stock of the same variety contracted 4 per cent spindle-tuber while the fifth row contracted none. In Field 31, the first row of healthy Spaulding Rose nearest to spindle-tuber Irish Cobblers contracted 3 per cent spindle-tuber while the fifth and following rows contracted none. In Field 5, in healthy Green Mountains the first, fifth, tenth, and twentieth rows counting away from mosaic stock of the same variety (north side) contracted respectively 48, 20, 14, and 2 per cent mosaic. In Field 11, in healthy Green Mountains the first, fifth, and tenth rows counting away from mosaic stock of the same variety (east side) contracted respectively 42, 28, and 12 per cent mosaic. In Field 5, in healthy Green Mountains the first, fifth, and tenth rows counting away from mosaic Spaulding Rose stock (south side) contracted respectively 16, 14, and 6 per cent mosaic. In Field 25, in healthy Green Mountains the first row next to mosaic Spaulding Rose stock contracted 14 per cent mosaic while the fifth and following rows contracted 8 per cent or less. In Field 22, in healthy Green Mountain stock the first row next to leafroll Irish Cobblers (north side) contracted 3 per cent leafroll while the fifth and following rows contracted none.

Here the only very convincing evidence of spread is of mosaic in Fields 5 and 11. In some of the other examples only a small percentage of the disease was noted in the progeny. This, together with either the presence of the disease in distant rows, or the record of a trace of disease in the sampled field in 1923, makes it somewhat doubtful whether spread occurred from one field or stock to another. There is least doubt in regard to the spread of spindle-tuber in Fields 25, 27, and 31. In these fields the spread was slight, in contrast to seven instances of greater spread observed in the previous series of samples (1922-1923).[9]

In Nebraska "experiments showed that spindle-tuber is transmitted across several rows of plants, but that most infection occurs in the rows near by."[10] More in detail, in 1923 there were "planted normal tubers in blocks adjacent to blocks of spindle-tubers. The progeny was planted in 1924. During that season it was quite evident that spindle-tuber had been transmitted to plants in the 4th row removed from the spindle-tuber blocks."

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[9] *Ibid.* p. 19.

[10] Werner, H. O. Spindle-tuber—the cause of "run out" potatoes. Nebraska Potato Imp. Assoc. 6th Ann. Rpt. p. 57-79. 1924. See p. 74.

Again, "normal tubers.....were planted from one to six rows removed from spindle tubers in 1924. As the distance from the spindle tubers decreased the percentage and severity of the infection increased but it was still very severe in the 6th row."[11]

In Indiana it was found in regard to leaf roll that "the percentage of seasonal infection decreases with increasing distance from the leaf roll plants and it would appear that there is not much danger of the disease spreading from one field to another if the latter are well separated."[12]

Most spread to nearest group of rows. Spindle-tuber seems to have spread in Field 5 from diseased Green Mountains to the first five rows of healthy Green Mountains (north side) and from diseased Spaulding Rose stock to the first five rows of Green Mountains (south side), without going farther. In Field 7 (west side) spindle-tuber apparently spread from diseased Green Mountains more to the first five rows of healthy Irish Cobblers than beyond, though going to the fiftieth row. Spindle-tuber also spread in Field 11 (west side), from diseased Irish Cobblers across a space 80 feet wide containing grass, weeds, and a road, then across 45 rows of unusually vigorous, healthy Green Mountains. In Field 17 rugose mosaic, which is rare in commercial fields in the locality, spread across an interval of 35 feet containing no potatoes to the first ten rows of healthy Irish Cobblers, but not beyond.

More disease increase with greater distance. In Field 10 spindle-tuber increased in Irish Cobblers as the samples were taken farther from diseased Spaulding Rose stock. Here some spindle-tuber was present the year before, so that the results may be due to differences in hill-to-hill spread rather than to greater spread with greater distance from the Spaulding Rose stock. A similar instance is seen in Field 19, where mosaic in Green Mountains increased more with greater distance from Spaulding Rose. Here the Green Mountains had an undetermined amount of mosaic rogued before being sampled in 1923 and, even with from 8 to 16 per cent mosaic, were unusually healthy for being grown for the fourth consecutive year in this region, so that it is not considered proved that the disease spread from the Spaulding Rose stock. In Field 30 spindle-tuber was contracted by a small percentage of hills in the twelfth row of healthy Irish Cobblers but by none in the first and fifth rows distant from diseased Spaulding Rose stock. In Field 26 spindle-tuber was contracted by a small percentage of hills in healthy Green Mountains in the twentieth and fortieth rows from diseased Irish Cobblers, but not in other rows.

In Fields 26 and 30, spindle-tuber possibly was carried by flying insects irregularly as to distance. In Field 6-A the disease was recorded as being absent in 1923 but sampled 2 per cent in 1924. Rather than to consider this as an instance of spontaneous appearance, the writers would admit lack of detection of a small amount of disease in 1923, when considerable traveling and sampling were necessarily crowded into the time spent on this problem.

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[11]Werner, H. O. Mid-season potato notes from Nebraska. Potato News Bul. 2:375-377. 1925.

[12]Gardner, Max W., and James B. Kendrick. Potato leaf roll in Indiana. Indiana Agr. Exp. Sta. Bul. 284. 1924. See p. 17.

Spread to both nearest and farthest rows. In Field 34, at first glance there seems to have been much spread of spindle-tuber to the first row of healthy Spaulding Rose stock, and then more spread with greater distance. However, the recorded percentages for the preceding year, varying from 3 to 13 per cent, explain the facts on the basis of hill-to-hill spread, because a lower or higher percentage in a row the first year resulted generally in a corresponding lower or higher percentage the second year. In Field 11, as noted previously, in healthy Green Mountains there was a convincing correlation between proximity and mosaic increase in the first ten rows next to diseased stock. Beyond that, also, there was an increase in mosaic. Whether this was due to greater proximity to diseased Irish Cobblers across the road, from which spindle-tuber spread, or to greater spread with greater distance from the Green Mountains, is problematical. The latter explanation is reasonable, since dispersing flying insects might scatter over to the road and settle down in greater numbers on the rows next to the road. Other instances of greater increase of disease in the nearest and farthest rows (Fields 2, 9, 19, and 23) probably belong to a later section of this bulletin regarding hill-to-hill spread.

General spread or increase. General spread or increase, with the possibility or probability of its being the result of hill-to-hill spread rather than of row-to-row or field-to-field spread, occurred in Green Mountains in regard to mosaic in Fields 1, 2, 3, 3-A, 3-B, 5-A, 6-A, 9, 9-A, 11-A, 13, 18-A, 19, 20, 21, 22, 23-A, 25, 26, 27, 29, 32-A, 32-B, 33, 35, and 35-A. The amount of increase from 1923 to 1924 differed among fields. For example, in Field 28 there was 1 per cent mosaic in 1923 and from 0 to 2 per cent in 1924 (varying with the location of the sample.) In Field 9 the increase was from 2 to 4 per cent appearing in 1923, to from 11 to 29 per cent shown in 1924. In Field 2 the increase was from 5 to 10 per cent in 1923, to from 25 to 64 per cent in 1924. The mosaic percentage for the two years increased from 30 per cent to 68 per cent in Field 32-A, from 50 per cent to 93 per cent in Field 35-A, and from 96 per cent to 100 per cent in Fields 5-A and 32-B. These examples suggest a generally progressive increase from year to year in any one strain. Such an increase has been observed in a number of strains grown for several years in this region, in the absence of control measures.

Similar general spread or increase occurred in Green Mountains in regard to spindle-tuber in Fields 1, 2, 5-A, 7-A, 9-A, 11-A, 21, and 32-B. Here also the amount of season-to-season increase varied, being in Field 21 from a trace in 1923 to from 0 to 11 per cent in 1924, in Field 35-A from 2 per cent to 3 per cent for the two years, in Field 9-A from 2 per cent to 14 per cent, in Field 1 from 5 per cent in 1923 to from 10 to 20 per cent in 1924, in Field 7-A from 20 per cent to 36 per cent, and in Field 5-A from 40 per cent to 70 per cent.

In Irish Cobblers, spindle-tuber increased in Fields 4-A, 7-B, 8, 9-B, 10, 11-B, 12, 12-A, 14-A, 16-A, 21-B, 24, 26-A, 27-A, 31-A, and 36-A. Examples of increase from 1923 to 1924 are Field 12, 1 per cent to from 0 to 6 per cent; Field 31-A, 7 per cent to 47 per cent; Field 26-A, 25 per cent to 43 per cent; Field 27-A, 50 per cent to 56 per cent; and Field 21-B, 60 per cent to 80 per cent.

Spindle-tuber increased generally in Spaulding Rose Fields 5-B, 10-A, 14, 22-B, 32-C, and 34.

No spread or increase. In the absence of any roguing, mosaic either decreased, remained the same, or showed an insignificant increase, in Green Mountains in Fields 7-A and 28, and in Spaulding Rose in Fields 5-B, 10-A, 19-A, 23, 32-C, and 33-B. The same is true of spindle-tuber in Green Mountains in Fields 23-A and 35-A, in Irish Cobblers in Fields 8-A and 14-B, and in Spaulding Rose in Fields 19-A, 20-A, 23, 25-A, 33-B, and 34-A.

Mosaic was not found in Field 34, Spaulding Rose, or in the progeny of the samples. No conclusions are drawn about mosaic in Irish Cobblers, because of the existence in this variety of a type of mosaic that is of uncertain diagnosis due to varietal modification of the symptoms and due to confusion with similar effects from environmental conditions. No Green Mountain stock was observed that was entirely free from mosaic in both seasons. Spindle-tuber however was not found in Green Mountains of Fields 3, 13, 15, 18-A, 28, 29, 32, and 32-A; or in Irish Cobblers of Fields 4, 6, 18, and 36 except for a trace the first year which apparently was not included in the sample lots. These fields will be considered again in the section on "effect of isolation".

Field-to-field spread compared with hill-to-hill spread. Here a "field" is considered as a continuous area planted with one stock, so that in a field in the ordinary use of the word, there may be two adjoining "fields" of different stocks or two separated "fields" of the same stock as "field" is meant in this bulletin. The preceding sections of this bulletin on "most spread to nearest single row" and "most spread to nearest group of rows" show that field-to-field spread of disease sometimes occurs. The section on "general spread or increase" shows that it is still more common for hill-to-spread to occur in a partly diseased stock.

Where mosaic or spindle-tuber most obviously spread from one field to another, in Fields 5, 7 (west side) and 11 (east side), there was also marked spread from hill to hill in the corresponding adjoining diseased fields 5-A, 5-B, 7-A, and 11-A. There was less spread than in the preceding fields, both from row to row in Field 7 (east side) and from hill to hill in Field 7-B. In the most probable instances of slight spread from field to field (in Fields 25, 27, and 31) there was sometimes slight hill-to-hill spread in the corresponding diseased fields (25-A and 27-A) and sometimes marked spread (Field 31-A.)

Effect of isolation. As is pointed out in preceding paragraphs on "no spread or increase", spindle-tuber remained absent in twelve fields. These either were fields adjoining others with no spindle-tuber or practically none (Fields 6, 13, 18, and 18-A), or were isolated from the nearest diseased fields by distances varying from 15 to 1250 feet (Fields 3, 4, 15, 28, 29, 32, 32-A) with the exception of Field 36 which was not isolated. As an interesting example, in Field 4-A spindle-tuber increased from 25 per cent to 57 per cent while 40 feet away across a road, healthy stock in Field 4 was not contaminated, as far as was shown by the samples. Again, the disease increased from 14 per cent to 29 per cent in Field 15-A while 15 feet distant a sample of healthy stock (Field 15) was not contaminated. In this connection it will however be remembered that in Field 11 (west side) the

disease appeared to have spread 80 feet across a road. This field and Field 9 (south side) are the only isolated fields to which the disease apparently spread from another field. Therefore separation of fields usually helped to reduce field-to-field spread, although it was not always sufficient to do so. Of course no amount of separation or isolation of fields would prevent hill-to-hill spread within a field.

Spread of mosaic compared with spread of spindle-tuber. It has already been shown in this bulletin that field conditions vary considerably in regard to the variety, the kind of disease, and the percentage of disease, and in the rate of spread, even with other conditions similar. Consequently a fair comparison of the spread of mosaic with that of spindle-tuber is difficult. Such a comparison seems useful only in the one variety where they can both be distinguished with a fair degree of certainty. This is in the Green Mountains.

In Field 1 there was 5 per cent of each of these two diseases in 1923. In the progeny of the several samples, in 1924 there was from 6 to 40 per cent mosaic, averaging 24 per cent, and from 10 to 20 per cent spindle-tuber, averaging 13 per cent, which is less than of mosaic. In Field 2, mosaic appeared in from 5 to 10 per cent of the hills in 1923 and in from 32 to 64 per cent, averaging 42, in 1924, while the corresponding percentages for spindle-tuber were an average of 3 per cent for 1923 and 10 per cent for 1924,—less increase than of mosaic. In Field 5 (north side) the samples from the first, fifth, tenth, and twentieth rows were respectively 48, 20, 14, and 2 per cent mosaic and 6, 8, 0, and 0 per cent spindle-tuber. Here the greater spread of mosaic, from Field 5-A, may be due in part to the presence of more mosaic there—96 per cent as against 40 per cent spindle-tuber.

TABLE 10.

Increase of mosaic and spindle-tuber in Green Mountain stocks.[1]

Field	Mosaic		Spindle-tuber	
	1923	1924	1923	1924
	%	%	%	%
5–A	96	100	40	70
7–A	94	94	20	36
9–A	11	46	2	14
11–A	65	96	2	8
23–A	80	97	7	7
32–B	96	100	4	11
35–A	50	93	2	3

[1]Data transcribed from Table 9.

In the other Green Mountain fields studied, often spindle-tuber was absent and when both diseases were present mosaic was more abundant than spindle-tuber. This might be due either to spindle-tuber being easier to reduce by tuber selection or to its spreading less rapidly in the field, either in the region here concerned or in the regions from which the seed stocks came. The results of hill-to-hill spread in the fields where the two diseases

were present are given in Table 10. There it is seen that even for a given original percentage of one disease, the increase might be different. For example, 2 per cent spindle-tuber increased to 14 per cent in Field 9-A and to only 3 per cent in Field 35-A. Again, about the same percentage of mosaic resulted in Fields 35-A, 11-A, 23-A, and 7-A, namely from 93 to 97 per cent, although the percentage for the preceding year differed for these fields being respectively 50, 65, 80, and 94. Such variations in spread or increase have been repeatedly observed in experimental lots that were larger than these samples. With allowance for the difference in the amount of disease originally present and for variations in the degree of spread in the same disease, it seems that in Green Mountains spindle-tuber increases about as rapidly as mosaic when no tuber selection is attempted.

Direction of spread. Several fields happened to be situated with diseased fields adjoining, or near, on opposite sides so that the spread of spindle-tuber from opposite directions could be studied. In Field 5 the disease spread more from the north than from the south, in accordance with the presence of more spindle-tuber in the diseased field on the north. In Fields 9 and 22 the disease spread more from the south than from the north, in spite of there being less spindle-tuber in the diseased fields on the south. In Fields 7 and 11 the disease spread more from the west than from the east, in the former in spite of there being less disease on the west and in the latter in accordance with more on the west. Evidently no general conclusion can be drawn yet as to the prevailing direction of spread of disease.

Parts of one strain in different places. The same Irish Cobbler strain, according to information from the various growers, was planted in Fields 6, 7, 8, 8-A, 9-B, 10, 17, and 18. Seed from this strain had not been obtained from the original grower all in the same year for these different fields, however. Spindle-tuber was most abundant in the stock that had been away from the original grower the longest, probably because of contamination resulting either from too great proximity in the field or from accidental admixture in storage. The only parts of this strain still free from spindle-tuber in 1923 were in Field 6 on the originating farm (where the grower claimed to have started the strain from one plant), and two stocks that were off the originating farm for the first year. In the latter, one stock became contaminated up to 4 per cent spindle-tuber in 1923 because of spread from adjoining diseased fields (Field 7) while the other was planted adjoining a healthy stock and remained free from spindle-tuber (Field 18.)

Green Mountain Strain J of the preceding publication[13] was sampled in four fields in 1923, where a trace of mosaic after roguing and a trace of spindle-tuber were observed. This was the third year in this region. Most Green Mountain stocks here for that length of time had been exposed to disease contamination in the field and had become more diseased. Even in this strain, one stock[14] had become contaminated in 1922. In the four fields of Strain J that were sampled in 1923 (Fields 19, 20, 21 and 22) the amount

[13] *Ibid.* p. 24.

[14] *Ibid.* Table 4, p. 14, Field 29.

of disease increase from hill-to-hill spread differed, for mosaic being up to 12, 3, 8, and 6 per cent respectively, and for spindle-tuber being up to 2, 1, 3, and 0 per cent respectively.

Harboring of mosaic by Irish Cobblers and Spaulding Rose. Each of the several kinds of mosaic now known in Green Mountains may vary as to appearance or symptoms, even in one variety, at different times in the season and in different seasons or climates. Some kinds of mosaic may also appear less conspicuous in varieties other than Green Mountains. Evidence of the contamination of Green Mountains from Irish Cobblers or Spaulding Rose with the two latter showing obscure symptoms or no symptoms of mosaic, appeared only in Fields 5 (south side), 11 (west side), 15 (north side), and 25 (south side.) In regard to Field 11, reference should be made to a preceding section on "spread to both nearest and farthest rows," where another manner of spread is suggested.

Partly diseased tuber-units. Reference was made in a preceding publication[15] to the fact that mosaic or spindle-tuber is not always completely distributed throughout a diseased tuber, so that sometimes both healthy and diseased hills can be grown from the same seed tuber. The Green Mountain samples of Tables 8 and 9 were planted by tuber-units, each seed tuber being cut into two seed-pieces. From the healthy fields, 766 tubers were dug that were mosaic, and of these 766 mosaic tubers there were 40 (or 5.2 per cent) that were incompletely diseased as shown by differences between the hills comprising the tuber-units. Also, 25 tubers were leafroll and of these, 4 (or 16 per cent) were incompletely diseased. From the diseased fields, 420 tubers were dug that were mosaic and of these 420 mosaic tubers only 3 were incompletely diseased. Apparently hill-to-hill spread was much more effective in the diseased fields, in completely contaminating the still healthy tubers, than where the source of disease was smaller in amount. Some tuber-units were also noted that were incompletely infected with spindle-tuber.

Number of aphids counted. For various probable reasons, some of which have been pointed out previously[16], there is no evident correlation between the aphid counts of Tables 8 and 9 and the varying degrees of spread of disease. Aphids were generally present. More detailed records as to aphids were made in certain fields, and will be described in the next section of this bulletin.

EFFECTS OF ROGUING FIELDS AND SEED PLOTS

The old process of roguing[17] is still applied each year in a number of commercial fields and seed plots in order to reduce, and eliminate if possible, varietal admixtures and diseases among

[15] *Ibid.* p. 24-25.

[16] *Ibid.* p. 25-26.

[17] Sometimes written "rogueing" in spite of such usage as is indicated by "intriguing" and "roguish."

which are those considered in this bulletin. It will be remembered that the results of roguing are not fully apparent until in the next season. Some of the first tests of roguing by the writers were carried on before the infectious nature of mosaic and related maladies were known, and the value of these tests was reduced somewhat insofar as control by the roguing was concerned, because of the rogued plots being narrow and being planted next to diseased plots.[18]

Aroostook Farm Seed Plot in 1921

In 1921, an isolated machine-planted Green Mountain seed-plot on Aroostook Farm was rogued of about 10 per cent, of which about 8 per cent were mosaic and the remaining 2 per cent were leafroll and spindle-tuber. Seed saved from parts of this plot that had been partly freed of aphids temporarily by a nicotine spray, produced stock that was 18 per cent mosaic and 2 per cent spindle-tuber in 1922. This doubling of the disease percentage was not encouraging.

Aroostook Farm Seed Plot in 1922

In 1922, different seed of the same variety was used in a similar seed-plot on Aroostook Farm. Three per cent mosaic was rogued out in that year but there was from 5 to 10 per cent in the various parts of this stock in 1923. There was more spindle-

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[18]Schultz, E. S., and Donald Folsom. Transmission of the mosaic disease of Irish potatoes. Jour. Agr. Res. 19: 315-337. 1920. See p. 330. ———————Transmission, variation, and control of certain degeneration diseases of Irish potatoes. Jour. Agr. Res. 25: 43-117. 1923. "Roguing with no insect spraying and with no great degree of isolation has been tested for several years, 1917-20, by the writers. With variations according to the season and degree of proximity to diseased plots, the general results have been to keep the amount of mosaic in the stock about the same from year to year, between 13 and 30 per cent, except that roguing in 1920 was followed in 1921 by 35 per cent and 65 per cent in Green Mountains and Bliss Triumphs. This was a gain over conditions in unrogued parts of the same strains. Why the removal presumably of all diseased hills has not eliminated the disease, or at least steadily decreased the percentage, is not certain. Possible causes are masking of symptoms at the time of roguing, dispersal of transmitting insects from rogued plants before or after these plants are pulled and insect dispersal from unrogued plots." (On p. 106).

tuber in this stock than in the 1921 seed-plot and an attempt to rogue it out was soon discontinued because of the difficulty of distinguishing diseased hills. In this 1922 seed-plot the mosaic was rogued out mostly by July 4 and entirely by July 24. Examination for aphids disclosed none until after July 15, and only 10 per plant on July 21 and 100 per plant on August 5; 500 per plant is not a severe infestation for this region. Samples dug on August 5 showed nearly as much mosaic the next year as samples dug later, though the September 15 sample, dug after the peak of the aphid infestation had passed, showed the most. Moreover, nicotine spraying in a 24-row strip on August 22 reduced the aphids from 700 per plant to 25 per plant, and yet there was more mosaic in seed from the sprayed section than from elsewhere. It therefore seems that aphids were not the only agency transmitting mosaic from one hill to another, but that some other agency was functioning, probably before it was possible to detect mosaic and rogue it. With spindle-tuber however, the spraying mentioned seemed to help. This disease did not spread quite as much here as mosaic did, and the removal of diseased hills and adjacent healthy hills at digging time eliminated it in the sprayed strip, but not elsewhere.

AROOSTOOK FARM SEED PLOT IN 1923

In order to make certain diseases such as spindle-tuber more conspicuous, and to reduce the chance for each diseased hill to contaminate adjacent hills, the seed-plot in 1923 was planted by hand by tuber-units. That is, the furrow was opened and fertilized with a planting machine and in it the pieces of each seed-tuber were planted later by hand at one time in consecutive hills. As has been shown in preceding pages of this bulletin, usually a tuber is completely diseased if not healthy, so that when a stock is planted by tuber-units most of the diseased hills are grouped and attract the attention more. Also, only two healthy hills adjoin a group of hills in a diseased tuber-unit, while several healthy hills adjoin the diseased hills from one tuber if they are scattered by machine planting. The effect of having fewer healthy hills adjoining diseased hills is of value from the greater ease of removal of diseased hills without disturbing the healthy hills, as well as from less danger of spread of disease. (See p. 107).

TABLE 11.

Degeneration diseases in stocks planted by tuber-units and rogued in 1923.

Variety	Strain	Mild mosaic		Rugose mosaic		Leafrolling mosaic[1]		Leafroll		Spindle-tuber		Giant-hill	
		1923	1924	1923	1924	1923	1924	1923	1924	1923	1924	1923	1924
		%	%	%	%	%	%	%	%	%	%	%	%
Green Mountain	A	1.2	4	0	0.6	0	0.7	0.5	0.2	0	0.6	P[2]	2
	AA[3]	0	3	0	0	0	0	0	0	0	1	?[4]	5
	B	10	11	0	0.3	1	1	2	0	6	12	?[4]	P[5]
	C	0.1	2	0	0	0	0	0.1	0	0	0	?[4]	P[5]
	D	0	5	0	1	0	0	0	1	0	0	P[2]	P[5]
	E	12	3	0.3	0	0	0	3	0	11	4	?[4]	P[5]
	F	12	6	1	0	0.3	0	0.6	0	6	1	?[4]	1
Irish Cobbler	A	0	0	0	0	0	10	0	2	0	2	?[4]	?[6]
	AA[3]	0	0	0	0	0	7	0	0	0	2	?[4]	?[6]
	B	0	0	2	0	8	0	0	0	37	8	?[4]	?[6]
	C	0	0	0	0	0	H[7]	0	0	83	H[7]	?[4]	?[6]
	D	0	0	0	2	6	H[7]	0	0	19	9	?[4]	?[6]
	E	0	0	0	0	7	18	0	0	7	0	?[4]	?[6]
Bliss Triumph[8]		57	29	3	0.7	0	0	0	0	4	0	?[4]	?[6]
Spaulding Rose[8]		0	0	0	0	3	2	0	0	10	1	?[4]	?[6]
Russet Rural		0	0	0	9	4	3	0	0	0	2	?[4]	?[6]

[1]Similar to mild mosaic in the first part of the season in Green Mountains, and hard to detect in Irish Cobblers.

[2]Presence indicated by a record of a certain type of "admixture," found in 1924 to be giant hills.

[3]Originally of the same strain as A.

[4]No data available.

[5]Present but percentage not determined.

[6]None recognized, but possibly some was present.

[7]High; all suspected units removed too early in the season for certainty of diagnosis, as seasonal conditions caused confusing injury.

[8]Mosaic diagnosis in this variety is still somewhat uncertain as to types of mosaic as named for the Green Mountain variety.

The seed-plot in 1923 was planted with several Green Mountain strains and with small lots of several other varieties. The amount of disease rogued out in 1923 and appearing again in 1924, is given in Table 11. There it is seen that mild mosaic was reduced in Green Mountain strains E and F and in the Bliss Triumph strain but that it increased in Green Mountain strains A to D. These last strains probably became contaminated from strains B, E, and F, which were the only strains of this variety with an appreciable amount of mosaic in 1923. The increase in strain B, contrasting with a decrease in strains E and F, is correlated with the securing in 1923 at harvest, of the strain B perpetuation or seed stock from the second row from the outside of the seed-plot,

near an area planted in potatoes the preceding year. In such an outside row usually flea beetles and other hibernating potato insects are more abundant than in the middle of a plot, where strains E and F were. This possibility of insects other than aphids functioning as agencies of transmission was mentioned in this bulletin in connection with the 1922 seed-plot as well as in previous publications.[19] The relationship between aphid counts and spread of mosaic in the 1923 seed-plot and other fields is shown in Table 12.

Table 12 gives some interesting facts. The aphid infestation in the seed-plot was about two weeks later than in the unrogued field. This is probably due to the aphids being mostly of the species over-wintering on rose-bushes, together with the seed-plot being over a half-mile farther than the unrogued field from the nearest rose-bushes, which are mostly cultivated or escaped (not native) in this immediate locality.[20] The major part of the mild mosaic infection reached the tubers in both fields at the same time with the rise of the aphid count to about 30 per five-leaf sample, this being of course about two weeks later in the seed-plot. The usual August brood of flea-beetles did not appear. Two explanatory theories are presented. Either aphids spread mosaic in the unrogued field from diseased to adjacent healthy hills, and not to other hills, with a very short period between inoculation

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[19]Schultz, E. S., Donald Folsom, F. Merrill Hildebrandt, and Lon A. Hawkins. Investigations on the mosaic disease of the Irish potato. Jour. Agr. Res. 17: 247-273. 1919. "Whether it is possible entirely to eliminate mosaic by roguing has not been proved." "Insects of all kinds should be kept off the seed plot by adequate spraying." (P. 270).

Folsom, Donald. Potato mosaic. Maine Agr. Exp. Sta. Bul. 292. 1920. "It is quite probable that sucking insects other than aphids contribute to the spread of mosaic." (P. 175).

Patch, Edith M. Rose bushes in relation to potato culture. Maine Agr. Exp. Sta. Bul. 303. 1921. "We believe, from a series of apparently convincing circumstantial evidence, that the pink and green potato aphid is the insect most concerned with the field transference of potato mosaic in northern Maine." "The possibility that certain other potato insects may be able to carry diseases should not be overlooked." (P. 341).

Folsom, Donald, and E. S. Schultz. The importance and natural spread of potato degeneration diseases. Maine Agr. Exp. Sta. Bul. 316. 1924. "In Ireland the transmission of one potato degeneration disease (leafroll) has been demonstrated by means of other insects in addition to aphids (leaf-hoppers, capsid bugs, and flea beetles.) (P. 26).

[20]Patch, Edith M. *Op. cit.* P. 334-335.

by the aphids and tuber infection, and then carried the disease to the rogued seed-plot a half-mile distant; or else some other agency spread mosaic early in the season in both places, with a long period between inoculation and tuber infection, and probably with further spread by aphids and other insects later in the season. The second theory appeals much more to the writers, considering available facts concerning the length of the incubation period of mild mosaic, the distance of spread between fields, and the spread of other kinds of mosaic early in the season while aphids are still extremely rare.

TABLE 12.

Comparison of aphid counts and mild mosaic in Green Mountains harvested early in 1923.

Date of aphid count or of harvest	Tuber-unit seed-plot[1]		Unrogued field[4]		
				Mosaic in healthy hills[3]	
	Aphids[2]	Mosaic in healthyhills[3]	Aphids[2]	Adjacent to mosaic hills	Not adjacent to mosaic hills
		Per cent		Per cent	Per cent
July 5	0	——	0	——	——
July 14	0	——	0.3	——	——
July 20	0	——	0.3	——	——
July 28	0	——	3	——	——
August 2	0.1	——	6	——	——
August 8	0.1	0	9	4	0
August 17	6	0	32	33	0
August 25	6	0	109	46	0
September 1	28	10	174	67	2
September 22	——	15	——	52	0

[1]Rogued mostly on July 26 to 28, and practically all by August 2. Early-harvest samples dug in outside row where no tuber-units had been rogued near-by.

[2]Aphid counts given for July 5 and 14 are the averages for 10 to 20 three-leaf samples, and afterwards are for five-leaf samples. Reference is made to the compound leaves and not to leaflets. A sample represented the different parts of a plant, and should be multiplied by about 5 to give the number per plant.

[3]Mosaic percentage here is got from the tuber units grown in 1924.

[4]Field 1 of Table 8 (5 per cent mosaic in 1923 and 6 to 40 per cent mosaic in 1924.) Also fifth part of Table 1 (10 per cent mosaic in 1924.)

Returning now to the fact that mild mosaic was not actually reduced in strain B of Table 11, by roguing in a tuber-unit seed-plot, it should be pointed out that such roguing in the past had helped considerably to keep down the natural increase of mosaic in this stock. This stock, healthy in 1920 and about 7 per cent mosaic in 1921, was about 45 per cent mosaic in an unrogued part in 1923 and about 60 per cent in 1924, while in an annually

rogued part it was only 11 per cent in 1924. Similarly, strain E, only 3 per cent mild mosaic in 1924 in the part from the seed-plot in question, was 10 to 40 per cent in unrogued parts from other fields. It must also be admitted that the reduction in Bliss Triumphs from 57 to 29 per cent was encouraging.

As Table 11 shows, rugose mosaic remained unimportant except in the Russet Rurals. Leafrolling mosaic became more recognizable to the writers in the Irish Cobblers and became no worse in other varieties. Leafroll was reduced, as it had been in previous roguing tests even in machine-planted stock. Spindle-tuber increased in Russet Rurals and in the Green Mountains near the outside of the plot where mild mosaic increased, but was reduced elsewhere. Giant hills and the witches' broom or yellow-top disease apparently increased somewhat, but had not been clearly recognized in 1923 at the time of roguing. In general, the results from the tuber-unit seed-plot on Aroostook Farm though somewhat puzzling were encouraging as a means for holding mosaic in check and for reducing spindle-tuber. On the seed-plot, as elsewhere in the locality, the other degeneration diseases were not threatening.

It should be pointed out here that the encouraging results secured on this seed-plot were got in spite of certain adverse conditions. Varieties were planted that when infected tend to mask the symptoms of certain diseases, which therefore were hard to rogue out. Some lots that were planted had high percentages of certain diseases. The tuber-units were planted without skips between them, which makes it easier to miss roguing an end hill of a diseased unit and also increases the chances of spread of disease from one unit to an adjacent one, as compared with planting with skips between tuber-units. The seed-pieces averaged an ounce in weight. Larger seed pieces remain more firmly attached and so are lost less often. They also force the plants so that roguing can be done earlier in relation to the seasonal infestation by insects, and would help to compensate for any reduction in yield due to the skips. It is thought that still better results could be secured in a seed-plot planted with one variety only, with a variety that shows diseases clearly, with a nearly healthy stock, with skips between tuber-units, and with two ounces or more cut to a seed-piece.

OTHER SEED PLOTS IN 1923

A comparison may now be made with certain other seed-plots on commercial farms several miles both to the east and to the northwest of Aroostook Farm. Fields 13 and 13-A of Tables 8 and 9 constituted together a two-variety tuber-unit seed-plot. In the former, Green Mountains, about 1 per cent was rogued for mild mosaic on July 17 and 23 and on August 23, mostly on the first date. On the last two dates the only disease was in several tuber units with mild mosaic in the upper parts of one or more plants. This might indicate symptoms from early current-season spread, except that all the plants in one tuber unit were thus infected, which seemed too much of a coincidence to be explained otherwise than by delayed appearance of symptoms, a phenomenon commonly associated with incomplete infection of seed tubers. Here there were only 4 aphids on a five-leaf sample by August 23. In spite of the roguing and the small number of aphids, about 4 per cent of the stock was mosaic the next year. Better results were secured with the Irish Cobblers (Field 13-A) in regard to spindle-tuber, for which disease 21 per cent of the tuber units were rogued out, mostly on July 17. A few apparently diseased hills were still found at the time of digging, but the 50-tuber sample of rogued healthy stock contained no spindle-tuber the next year. The same stock unrogued and grown on the same farm, was 44 per cent spindle-tuber the next year (Table 9, Field 12A). Aphid counts were 2, 5, and 50 per five-leaf sample on July 17, July 23, and August 23, respectively.

In Field 16 of Table 8 part of the same stock was planted as for the preceding, Field 13-A, but in a place about 12 miles distant. Also, it was planted over a week later in soil not so well prepared and shaded more by trees. About the same percentage was removed for spindle-tuber, but uneven growth of the plants made its detection less certain. Roguing was done later, mostly on August 1. Some of the disease was not detected until at the time of digging. By August 18 there were only 6 aphids per five-leaf sample. The samples dug showed 6 per cent spindle-tuber the next year. This is not so much of a reduction as in Field 13-A, but is more than in the Aroostook Farm seed-plot for the same stock (Table 11, Cobbler strain D, reduced from 19 to 9 per cent spindle-tuber). It also is a great improvement over the same

stock unrogued on the same farm, where the spindle-tuber increased from 18 to 32 per cent. (Table 9, Field 16-A.)

TABLE 13.

Disease in the 1924 Aroostook Farm seed plot and in the progeny of 1925.

Variety	Strain[1]	Mild mosaic		Rugose mosaic		Leafrolling mosaic		Leafroll		Spindle-tuber		Giant-hill		Yellow-top	
		1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925
Green Mountain	A	% 6	% 3	% 1	% T[2]	% 1	% T[2]	% T	% T[2]	% 1	% 1	% 2	% 1	% T	% T
	AA	5	3	0	0	0	0	0	0	1	1	5	T	0	0
	B	17	7	0	0	1	0	T	0	16	13	P[3]	0	?[4]	0
	C	2	3	0	0	0	0	0	0	0	0	P[3]	1	?[4]	T
	D	8	2	1	0	0	0	1	0	0	1	P[3]	1	T	T
	E	2	5	0	T	0	0	0	0	0	1	P[3]	1	?[4]	T
	F	9	4	0	1	0	0	0	0	1	1	1	1	T	0
Bliss Triumph		29	9[5]	1											

[1]Each strain designated as in Table 11.
[2]T[2] (trace) is less than one-half of 1 per cent.
[3]Present but percentage not determined.
[4]No data available.
[5]Including 3 per cent of a mild type and 6 per cent of a severe type.
[6]One unit in 4239.
[7]Two units in 4239.

Aroostook Farm Seed Plot in 1924

In 1924, most of the lots planted on the 1923 seed-plot were again planted by tuber-units. The amount of disease rogued out in 1924 and appearing again in 1925, is given in Table 13. There it is seen that mild mosaic was reduced in all strains except the two that had the least, in which it increased slightly. Thus there was a leveling process, apparently due to the spread of the disease by some agency with the power to disperse generally and easily. The decrease in the Bliss Triumphs is notable, coming as it does after having 57 per cent in 1923. Leafrolling mosaic and leaf-roll were practically eliminated. Rugose mosaic, spindle-tuber, giant-hill, and yellow-top hung on persistently, though the highest percentages were lowered. Altogether the progress made was encouraging.

Time of Spread of Diseases in 1924

Insect counts were made and selected hills were dug at different times during 1924 in order to learn more about a possible important agency of spread other than plant lice. This was done in several fields and plots in several parts of the State. In the Aroostook Farm seed-plot roguing was done at various times between July 7 and September 7. Mosaic appeared fairly early, while giant-hill was detected better toward the end of the season. In fact, giant-hill showed up best after frost when affected plants were still alive and the healthy plants were killed. The Dover-Foxcroft tuber-unit seed-plot was rogued by one of the writers on July 19 and 30, and the Corinna hill-lot seed-plot on July 16. Other data are given in Table 14.

It is seen that in the Aroostook Farm tuber-unit seed-plot there was no spread of mosaic to the 40 hills selected at different times as being healthy and distant (D) from where mosaic units had been removed. Slight spread had occurred to the hills selected on August 6 as being opposite (in the next row) to a rogued mosaic unit. This indicates that the hang-over of a small amount of disease from one season to the next is due in part to spread from diseased units, this spread occurring before the disease can be detected and rogued. As far as is known, root contact might be considered a possible means of spread as well as

TABLE 14

Comparison of insect counts and presence of degeneration diseases in Green Mountains harvested early in 1924.

Place	Date	Insects[2]	Proximity as to disease[1]	Progeny in 1925						Remarks
				Hill lots			Tuber units			
				Number	Mosaic	Leaf-roll	Number	Mosaic	Leaf-roll	
					%	%		%	%	
Aroostock Farm tuber-unit seed plot	July 1	Buckthorn aphid 2/30[3]; flea beetle holes 0 to 10 per leaflet[4]; few "bugs"								Plants up to 6 inches in height
	August 6	Aphids 0/50	O–M	10	20	0	50	4	0	
			D	10	0	0	43	0	0	
	August 18		D	10	0	0	42	0	0	
	August 30		D	10	0	0	37	0	0	
	September 14	Potato aphids 115/25; 1 flea beetle seen								
	September 27		D	10	0	0	32	0	0	
Aroostock Farm unrogued field	August 6	Potato aphids 3/50	A–M	9	0	0	49	0	0	
			D	10	20	0	60	3	0	
	August 18		A–M	10	10	0	54	4	0	
			D	10	0	0	61	0	0	
	August 30		A–M	10	40	0	37	16	0	
			D	10	0	0	71	0	0	
	September 10	Potato aphids 148/25								
	September 27		A–M	10	60	0	49	32	0	
			D	10	30	0	47	17	0	

Comparison of insect counts and presence of degeneration diseases in Green Mountains harvested early in 1924—Continued.

Place	Date	Insects[2]	Proximity as to disease[1]	Progeny in 1925						Remarks
				Hill lots			Tuber units			
				Number	Mosaic	Leaf-roll	Number	Mosaic	Leaf-roll	
					%	%		%	%	
Dover-Foxcroft tuber-unit seed plot	July 19	Tarnished plant bugs common, with their effects on 12 of 50 hills; flea beetle holes common								Diseased units rogued out
	July 30	Few aphids	A–M	19	36	0	178	6	0	
			O–M	20	40	0	170	5	0	
			A–LR	12	42	0	96	7	0	
			O–LR	20	15	0	115	3	0	
			D	19	36	0	105	7	0	
	August 20		O–M	6	0	0	33	0	0	
			O–LR	6	0	0	23	0	0	
			D	5	40	0	30	7	0	
Corinna hill-lot seed plot	July 16	One potato aphid seen; flea beetle holes numerous								Diseased hill lots rogued out
	July 31	Few potato aphids	A–M	10	20	0	44	7	0	
			O–M	20	0	0	83	0	0	
			O–LR	20	25	0	103	5	0	
			D	20	20	0	87	9	0	

Comparison of insect counts and presence of degeneration diseases in Green Mountains harvested early in 1924—Concluded.

Place	Date	Insects[2]	Proximity as to disease[1]	Progeny in 1925						Remarks
				Hill lots			Tuber units			
				Number	Mosaic	Leaf-roll	Number	Mosaic	Leaf-roll	
					%	%		%	%	
Highmoor Farm unrogued field	June 26	Aphids 0/30; flea beetle holes 15 to 50 per leaflet; "bugs" numerous, adults having eaten half of some plants								Plants up to 6 inches in height
	July 8	Aphids 2/50; several dozen flea beetles per plant; numerous young "bugs"								
	August 1	Aphids 26/75; young leafhoppers 3/75	A–M	10	10	0	43	2	0	
			A–LR	3	33	0	11	9	0	
			D	10	0	0	46	0	0	
	August 15	Aphids 56/50; leafhoppers 6/50; few flea beetles, many of their holes	A–M	9	89	0	53	49	0	
			D	10	20	10	51	20	4	
	August 28	Aphids 132/25	A–M	10	70	0	48	58	0	
			D	10	80	0	53	32	0	
	September 30	Aphids fungus-killed; flea beetles and tarnished plant bugs present	A–M	10	100	0	53	66	0	
			A–RM	2	100	0	11	73	0	
			A–LR	3	0	67	13	0	54	
			D	10	20	0	54	17	0	

[1]Hills adjacent to mosaic hills (A–M), adjacent to rugose mosaic hills (A–RM, included in preceding), adjacent to leafroll hills (A–LR), opposite mosaic hills (O–M), opposite leafroll hills (O–LR), or distant (D; not adjacent or opposite.)

[2]Technical names Aphis abbreviata (buckthorn aphid), Macrosiphum solanifolii (potato aphid; usually with an admixture of Myzus persicae), Epitrix cucumeris (flea beetle), Leptinotarsa decemlineata ("bugs"), Lygus pratensis (tarnished plant bug), and Empoasca mali (leafhopper). These have been kindly identified by Dr. E. M. Patch of this Station in cases of doubt.

[3]Aphid and leafhopper counts are the total (numerator) for the given number of leaves (denominator), the leaves in July representing equally the upper, middle and lower parts of the plant, and later representing 5 parts of the plant.

[4]Leaflet examined was the next to the last (distal) one.

insects. Aphids in this seed-plot were rare yet on August 6, but had been found there and can not be considered impossible as an agency of spread. The buckthorn aphids noted as being found on July 1 were wingless, which shows that wing-bearing aphids (from buckthorn bushes) had been there when the plants were small, and as pointed out previously[21] one aphid can transmit mosaic when potato plants are small.

The Aroostook Farm unrogued field was planted with the Green Mountain strain A of Table 13, but by machine instead of by tuber-units, and, as indicated, was not rogued. Here the spread from mosaic to adjacent hills (the next ones in the same row) was progressively greater at later dates of harvesting. On August 6, August 18, August 30, and September 27, the percentage of such hills (A-M) that had become infected was respectively 0, 10, 40, and 60, while the percentage of their tubers that the disease had reached was respectively 0, 4, 16, and 32 per cent. This greater spread with the advance of the season is correlated with longer duration of contact of roots and shoots, with the longer time permitting the virus to "diffuse" from the place of inoculation to the tubers, and with an increase in the number of aphids present. Which of these factors is important, if any are, remains to be shown by laboratory experiments now under way.

In this same field the hills selected as distant from mosaic hills (D) likewise became infected more at the last of the season, with some but not much previous infection. This lateness may be explained on the basis of spread by certain insects, possibly flying aphids, rather than by root contact.

In the Dover-Foxcroft tuber-unit seed-plot, mosaic had spread by July 30. Not all the mosaic could be ascertained yet when the plot was rogued on July 19, so that the disease was present to some extent until July 30 when the experimental hill selections were made. By July 30 the disease had spread similarly to plants adjacent to mosaic plants, opposite them, or distant from them, indicating a spreading agency that was active and generally distributed. Flea beetles and tarnished plant bugs were more numerous than aphids, the significance of which can be better

[21]Schultz, E. S., and Donald Folsom. Transmission, variation, and control of certain degeneration diseases of Irish potatoes. Journ. Agric. Res. 25: 43-117. 1923. See p. 84.

understood upon the completion of various insect transmission experiments that are now being carried on.

In the Corinna hill-lot seed-plot the tubers of each hill selected in 1923 were cut together into a sack in the storage house before planting time. Then they were planted mixed as a hill-lot. Here, as at Dover-Foxcroft, there was spread by July 31 that was not correlated with the degree of proximity to diseased plants.

With this method of planting, as against tuber-unit planting, seed cutting is done under more convenient conditions. On the other hand, there are certain disadvantages, due to the fact that disease if present is usually in some tubers of a hill-lot but not in all the tubers. If only the diseased hills of a hill-lot are removed, these usually being scattered, there are more adjacent healthy hills that are probably infected and left than in the case of tuber-unit planting where the diseased hills are mostly grouped together in units. If, on the other hand, the whole hill-lot is removed when only part of the hills in it are diseased, there is needless waste of labor roguing healthy hills. Also, with diseased hills scattered through a hill-lot it is about as slow and uncertain to detect spindle-tuber and giant-hill as in machine-planted stock. These diseases are hard enough to detect when brought out by the grouping of diseased hills in tuber-units. The hill-lot method has been more successful in this Corinna stock than it would be in many other stocks, because of there being only a trace of mosaic to begin with, and because of there being no spindle-tuber.

In the Highmoor Farm unrogued field, planted with the same stock as the Aroostook Farm unrogued field, there was also a similarity as to the progressive increase of mosaic in the healthy selected hills adjacent to diseased hills. On August 1, August 15, August 28, and September 30, the percentage of such hills (A-M) that had become infected was respectively 10, 89, 70, and 100, while the percentage of tubers that the disease had reached was respectively 2, 49, 58, and 66. Here aphids increased in abundance from June 26 (none found) to August 28.

The preceding paragraph refers to all kinds of mosaic together, most being of the mild type. In this field two healthy hills adjacent to rugose mosaic hills were as much infected by that disease at the end of the season as the larger number of hills was

by all kinds of mosaic, showing that in this place and season the rugose type of mosaic was as contagious as the other types.

In this same field the hills selected as distant from mosaic hills (D) likewise became more infected as the season progressed, but only so up to the third harvest, on August 28. Generally they showed less spread than in the case of the adjacent hills. This shows again that contact is not necessary, though it is helpful, for the spread of mosaic in the field.

The preceding paragraphs show that in the same field there was more spread with greater proximity to mosaic, either on Aroostook Farm or on Highmoor Farm, where diseased hills were not rogued out and where the progressive seasonal increase of disease was disclosed. But in the Dover-Foxcroft and Corinna seed-plots at the time of the second roguing there was as much spread without contact as with it. This does not bring out a difference due to locality as much as it emphasizes the desirability of reducing contact as much as possible both by grouping the diseased hills and by removing them as early as possible. Even when this is done, evidently there still should be an improvement in our present methods in order to eliminate a slight spread that occurs at or before the time of roguing, without contact being essential. What this improvement shall be depends on what our experiments disclose as being the agency of spread early in the season.

In the unrogued fields of two places, Aroostook Farm (in northeastern Maine) and Highmoor Farm (in southwestern Maine), the same Green Mountain stock was planted, as stated. The plants were several days more advanced at Highmoor Farm by July 1 than at Aroostook Farm, but the corresponding harvests were similarly earlier, except for the last one. As is obvious in Table 15, where each pair of columns compares the two places, healthy hills in contact with mosaic hills were diseased earlier, more generally, and more completely at Highmoor Farm. These healthy hills were in similar conditions in the two places as regards proximity to the source of new mosaic infection, but for some reason the same degree of proximity resulted in greater infection in the Highmoor Farm field. Corresponding to this difference there was a difference in insects, aphids developing earlier and flea beetles, leafhoppers, and "potato bugs" being more

abundant. These differences as to insects may or may not have been the cause of the difference in spread.

TABLE 15.

Comparison of spread of mosaic under similar conditions of proximity to disease in two parts of Maine, 1924.[1]

Harvest	Adjacent to mosaic hills				Not adjacent or opposite			
	Hills		Tubers		Hills		Tubers	
	A. F.[2]	H. F.[2]	A. F.	H. F.	A. F.	H. F.	A. F.	H. F
	%	%	%	%	%	%	%	%
August 1–6	0	10	0	2	20	0	3	0
August 15–18	10	89	4	49	0	20	0	20
August 28–30	40	70	16	58	0	80	0	32
September 27–30	60	100	32	66	30	20	17	17

[1]Transcribed from Table 14.
[2]Aroostook Farm (A. F.) in northeastern Maine and Highmoor Farm (H. F.) in southwestern Maine.

The greater spread of mosaic at Highmoor Farm is not so striking in the case of hills selected as not being adjacent, or in contact. This might be expected inasmuch as such hills are not uniform as to the degree of proximity to mosaic hills, and according to the laws of chance a larger number would have to be selected to bring out a difference between regions that is correlated with time of harvest. Even here, the selected hills showed in general more spread at Highmoor Farm.

Leafroll did not spread as much as mosaic, though there was apparently as much chance, as far as source of infection was concerned, in the Dover-Foxcroft, Corinna, and Highmoor Farm selections. The only leafroll spread discovered was at Highmoor Farm, where it was greatest in the hills adjacent to leafroll hills and dug on September 30.

Much of the infection appeared to be incomplete, not only in the selected hills but also in the tubers. Often only part of the hills of a tuber-unit were mosaic, and further they would sometimes show the disease late, in the upper part of the plant. As pointed out in relation to this condition in the studies on field-to-field spread, such incompleteness of infection is associated with lightness of natural inoculation. That is, the less a disease is being transmitted in a field, the greater will be the proportion of

tubers in which new infection is incomplete. This is not surprising according to our conception of the cause of mosaic as being something which takes time to go from one part of the plant to another and which does not always penetrate to all parts of the plant.

Size of Tuber and Disease

In planting a tuber-unit seed-plot the question comes up as to what is the best size of tuber. In a previous publication[22] some evidence was presented indicating that in partly diseased hill lots, mosaic was more common in the tubers that were apparently of the largest size, though this was "not marked enough to make it seem desirable to experiment further by selecting tubers according to absolute weight or size." Also, in another previous publication[23] the same correlation is described for leafroll. Therefore it is of interest to compare disease percentage and tuber weight for the stocks of Table 11. These were sorted into weight classes before planting in 1923 and 1924, in the course of carrying on another experiment in connection with the test of disease control by tuber-unit seed-plots. The comparison is made in Table 16 for the lots that contained enough disease to make it worth while. It will be noted that in regard to mild mosaic in 1923 in strain B and in 1924 in strain A, the classes of 9 ounces and over, combined, had decidedly more disease than the classes of less weights. But, in one of these strains (A) in 1923 in regard to the same disease, the 7 ounce class had the greatest percentage, and in mild mosaic in 1923 in strains E and F, and in spindle-tuber in 1923 in strains B, E, and F, the greatest percentage was in the 5, 6, or 8 ounce class. Evidently it is futile at present to attempt any general degree of disease reduction by selecting tubers on the basis of absolute weight. Weight should be considered however, in planting a tuber-unit seed-plot, inasmuch as from six to ten ounce tubers, cut into from four to six pieces, are about the best considering the convenience of handling when cutting and planting, the size of seed-piece desired, and the economy of use of soil when spaces are left between tuber-units.

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[22]Schultz, E. S., and Donald Folsom. Transmission of the mosaic disease of Irish potatoes. Journ. Agr. Res. 19: 315-337. 1920. See p. 317-318.

[23]Schultz, E. S., and Donald Folsom. Leafroll, net-necrosis, and spindling-sprout of the Irish potato. Journ. Agr. Res. 21:47-80. 1921. See p. 69-71.

TABLE 16.[1]

Comparison of tuber weights and disease percentages in seed tubers.

Variety	Strain	Year		12 oz. and more	11 oz.	10 oz.	9 oz.	9 oz. and more	8 oz.	7 oz.	6 oz.	5 oz.	4 oz.	3 oz.	2 oz.	1 oz.	Bin-run[2]
Green Mountain	A	1923	Total number	11	17	23	31	82	96	187	291	437	793	675			
			Per cent mild mosaic	0	6	0	0	1	0	4	1	2	1	3			
		1924	Total number	49	27	31	61	168	264	320	526	513	441	266	117		31
			Per cent mild mosaic	26	19	3	10	15	5	7	7	5	4	3	4		6
	B	1923	Total number	2	0	2	9	13	19	28	47	104	123	396			
			Per cent mild mosaic	0	- - - - - - -	0	56	38	11	14	10	9	10	8			
			Per cent spindle-tuber	0	- - - - - - -	0	11	8	21	11	2	5	8	2			
	E	1923	Total number	7	8	14	19	48	28	57	73	86	- - -	- - - - -	- - -		
			Per cent mild mosaic	0	25	7	16	13	14	10	16	9	- - -	- - -	- - -		
			Per cent spindle-tuber	0	0	29	5	6	11	9	11	14		- -	- -		
	F	1923	Total number	10	5	12	17	14	25	44	44	104	52	- - - -	- - -		
			Per cent mild mosaic	10	20	8	18	14	8	2	25	14	15				
			Per cent spindle-tuber	0	20	0	6	5	8	7	5	10	8				
Bliss Triumph		1924	Total number	- - -	- - - - -	- - - - -	- - - - -	- - - - -	- - -	- - -	38	45	54				
			Per cent mild mosaic		- - - - -	- - - - -	- - - - -	- - - - -			31	31	30				

[1]Concerned with certain strains of Table 11.
[2]Bin-run contained different weights, unsorted.
[3]Less than one-half of one per cent.

GENERAL CONCLUSIONS

The yield rate of healthy stock was about the same in these tests (in 1924 and 1925) as for the same healthy strains in 1923.[24] The reduction of yield rate by spindle-tuber and mild mosaic ran from 8 to 25 per cent compared with a reduction of from 20 to 40 per cent in 1923. Also there seemed to be less reduction by disease when present in 50 per cent of the hills or less, in 1924, while in 1925 there was more. In brief, in 1924 there was less advantage to be derived than in 1923 and in 1925 from having disease-free stock, as far as yield rate is concerned. However, there was a demonstrable injury from either of these two diseases especially when present in all of the hills. Still greater injury resulted from the lowering of quality by spindle-tuber, and from the presence of rugose mosaic.

Growers sometimes cite instances in which stocks with no apparent disease have yielded less than other disease-free stocks or less than other stocks with mild mosaic present. Such instances have also been observed and described in these tests. However, there was a correlation of yield rate with location and soil type, and the difference between healthy stocks was absent when they were compared elsewhere in the same series of plots. Comparison between two stocks on different areas, even on the same farm, therefore is not as reliable as a comparison in one area with parts of one stock alternating with parts of the other.

In regard to the effect of proximity and isolation upon the spread of disease in 1923, the general conclusions of the preceding year's tests were confirmed. That is, in preventing the increase of disease in a stock, various conditions may help, such as a smaller original amount of disease, greater distance from diseased stock, and the location or personnel of the farm. In addition, roguing tests show that for some unknown reason differences of location in a region and even in a field can cause differences in the effectiveness of certain methods of eradication. Consequently at present there can be no great degree of certainty in forecasting the outcome of a given method of roguing, of a given degree of isolation, or of the presence of a given percentage of disease. Further detailed work with possible transmitting insects seems

[24] Folsom, Donald, and E. S. Schultz. *Op. cit.* See p. 5-7, 26.

to be needed. Meanwhile, if a grower or any other person or agency desires to determine the amount of spread on any farm or under given conditions, the methods of proximity sampling used in these studies can be recommended, with some modifications. That is, a set of samples from rows at five-row intervals across a healthy field, with a tuber from each of fifty or more hills going into each sample, should indicate the extent of spread occurring from one field to another, when planted and grown the next year. In these studies the samples were usually too small and too few to serve their purpose best. Hill-to-hill spread can be demonstrated best by digging a group of healthy hills growing next to diseased hills and comparing them with healthy hills found not adjacent to diseased hills.

Even assuming that there may perhaps be an inherent difference between strains of the same variety, there is not necessarily uniformity between parts of the same strain. Divergence between parts of the same strain may be brought about at least by unequal amounts of infection by mosaic and spindle-tuber. Consequently it is not enough for a stock to have come at some time from a certain generally good farm or strain, because the disease observed and its probable increase for the next year also are important.

With these principles in mind regarding the injurious effects of disease, especially when more abundant in a stock, and regarding the tendency of disease to spread and to increase without enough regularity to permit accurate forecasting of events, the possibilities in advance warm-climate testing should be mentioned. Samples representing different stocks have been grown on a small scale in greenhouses and on a larger scale in the open field in a more southern region during the months from January to April to get an indication of what might be expected of the bulk stock in Maine in the summer. Such advance testing has given fairly satisfactory results. The methods that have been used could be improved. It could be done in conjunction with demonstrations, in seed-buying regions, of the merits of Maine seed stocks.

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Bulletin 327

STUDIES OF MILK SECRETION. XVI. PROGENY PERFORMANCE OF GUERNSEY SIRES' SONS. An important guide to success in constructive breeding. The material presented in this bulletin is a study of the average progeny performance for all Guernsey sires' sons where these sons have two or more Advanced Registry daughters. All records are corrected to the mature form production so that the average performance of these sons is directly comparable. The sons are tabulated under their sires and the average progeny performance of the sons of these sires is given for milk yield, butter-fat percentage and butter-fat.

The data are presented to show the variation in the sires' performance and that of his sons. The relation between the son's daughters' milk yields and the sire's daughters' milk yields. Butter-fat percentages and butter-fat are also tabled. The data show that a sire's progeny performance to some extent indicates what his son's probable progeny performance will be.

Bulletin 329

STUDIES IN MILK SECRETION. XVII. TRANSMITTING QUALITIES OF GUERNSEY SIRES FOR MILK YIELD, BUTTER-FAT PERCENTAGE AND BUTTER-FAT. The crux of the dairymen's breeding problem is the selection and maintenance of a bull transmitting high milk yield, butter-fat percentage and butter-fat. To intelligently make such a selection it is necessary to have certain information on the transmitting ability of the bulls within a given breed. Bulletin 329 furnishes this information in a study of the daughter's production in contrast to that of the dam for all Guernsey Advanced Registry sires having two or more daughters. Tables are presented showing the average daughter-dam difference in milk yield, butter-fat percentage and butter-fat for these bulls.